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THE FUNDAMENTALS OF MICHURIN BIOLOGY

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INTRODUCTION

Biology is the science of living nature, a subject which people have been studying since ancient times, though approaching it in different ways at different periods. Until recently most biologists considered it their sole duty to give as exact a reproduction of living nature as possible, to describe its existing structure by word, number, weight or other means, by a drawing or plan reflecting the facts that exist independent of man, and by the logical interpretation of these facts. This aspect of the biologist's work is of undeniable value. An exact description helps people to picture living nature as it is today, while an interpretation of the facts described helps to explain why it is such as we see it to be. Yet in the history of the development of biology there were individual scientists who were not content merely to make a photographic, immobile picture of living nature. In the past, too, there were among men of science investigators who

clearly saw that the constancy of living nature is relative (as regards a short historical period) —in parenthesis let us remark that it is just this constancy that makes it possible to give a true photographic picture—yet they were convinced that *today living nature is not what it was a thousand, ten thousand, or a hundred thousand years ago* and that *in a thousand, ten thousand, a hundred thousand years from now it will be different from the nature we see and describe today.* Such biologists were particularly frequent among investigators who had at least some knowledge of practical farming and, as a result, saw how man alters living nature by his agricultural work comparatively rapidly as compared with wild nature. Darwin was an outstanding representative of this type of biologist.

Lamarck and Darwin were the first to provide biological science with irrefutable proof that living nature develops. Darwin's theory of the evolution of life marked the beginning of a new stage in biology, of a new approach to the study of this branch of science. Contemporary biologists who acknowledge that living nature changes in the course of time strive to understand not only its existing structure, but also to learn the *laws governing its alteration in the course of time, in the course of history*. They no longer limit themselves to a passive description of living nature,

but perseveringly work to disclose the paths of its development and to elucidate the laws of development. As a result, more and more scientists in our days are beginning to acknowledge that *the role of the biologist is not that of a mere passive observer calmly depicting the present state of living nature.* Biology should strive to equip the farmer with a means of building up or remodelling living nature so that it may satisfy the needs of society ever more fully—a means which man needs now in order the better to solve this or that practical task.

Under our conditions, when we are engaged in building a communist society, the farmer needs scientific knowledge of the laws governing the development of living nature in order that he may more and more fully control nature and derive from it ever-increasing benefits indispensable or useful to man. We need the science of biology first and foremost to help the farmer raise the productivity of his labour, to make his work less dependent upon the elemental forces of nature, and in this way to contribute to the speediest transformation of agricultural labour into a form of industrial labour.

TASKS AND PRINCIPLES OF OUR BIOLOGICAL SCIENCE

Michurin biology is the science of the laws of development of living nature. We want to know these laws so that in our practical work we can turn the development of living nature in a direction useful to man.

Let us take a simple example.

An orchard with trees of only one variety of cherry, say the Vladimirskaya Roditeleva cherry, does not give a good yield of fruit. The trees may be sound and well-grown, but they will bear little fruit. The cherry tree gives a good yield only when the flowers of one variety are pollinated with pollen from the flowers of another variety. A good yield will be obtained only if in the orchard there are trees of another cherry variety—Shubinka, for example, growing next to the Vladimirskaya cherry. A still better yield is obtained when there are several varieties growing side by side in the orchard. Each variety of cherry needs pol-

lination by other varieties. Ignorance or disregard of this requirement leads to a drop in yields.

Take another fact. If at a distance from a field sown to rye, say, in a vegetable garden, we grow a single rye plant, it will come into ear and flower, but will produce no seeds or will give one, two, or three bad seeds from which puny plants with a low vitality develop in the next generation. The rye plant needs to be crossed with other rye plants.

Rye, maize and many other plants that man cultivates are classed among those whose flowers are normally pollinated only by the pollen of other specimens. These are cross-pollinating plants. Each flower of such plants must be fertilized by the pollen of another plant. In the field sown to one variety of rye cross-pollination takes place between different plants of the same variety. In cultivating rye the farmer constantly has to deal with intravarietal hybridization. If a rye plant of one variety is fertilized by the pollen of a rye plant belonging to a different variety intervarietal hybrid seeds are obtained. Numerous experiments conducted by Academician T. D. Lysenko and his collaborators, beginning as long ago as 1935, have demonstrated that hybrid seeds *of the highest quality and the highest yield are obtained from the cross-pollination of different varieties of rye.* The same results have been obtained for

maize, clover and other plants. The plants grown from the hybrid seeds are the most productive and the most resistant to disease.

In cultivating plants that are normally fertilized by alien pollen (cross-pollinators) it is not difficult to obtain hybrid seeds. It is enough to sow the seeds of two or three different varieties of rye in adjacent plots and the hybridization will take place of itself. All that is required here is the work of a scientific plant breeder who has studied which varieties should be taken for crossing in order to obtain the best hybrid seeds. It should be remembered that not every combination of varieties will give hybrids with valuable economic qualities.

The farmer has to deal not only with cross-pollinating plants but with self-pollinators, too. Every flower of such a plant is normally fertilized by its own pollen. Such plants, among them are barley, oats, wheat, peas and others, are self-fertilizing. Academician Lysenko has proved that among these plants free crossing (hybridization) within a variety, that is, free cross-pollination of plants belonging to the same variety, as well as the crossing of plants belonging to different varieties under conditions of free pollination, considerably improves the productivity of the seeds. The crossing of self-pollinating plants requires castration, i.e., the removal of

anthers from the flowers intended for the cross. After castration the flowers are freely pollinated by the pollen of all other plants growing nearby. As in the first case, here the work of the scientist is needed for the proper choice of plant varieties which will give the most highly-productive hybrid seeds as the result of free hybridization. The scientist must likewise help in perfecting the technique of castration. At the Lysenko All-Union Institute of Selection and Genetics simple methods of effecting such castration have been elaborated.

If the farmer is conversant with the laws of development of living nature he can use hybridization to change the breed, the heredity, of plants to man's advantage. By altering heredity he raises the yields of the plants he is cultivating and improves the quality of the harvest. Present-day Michurin biology has already worked out a number of methods of improving the productivity of seeds, among them, in the first place, hybridization, the training of seed plants, and so forth.

The farmer secures higher yields and an improvement in the quality of the products obtained from the cultivated plants by controlling and changing the conditions of life of plants.

The farmer of today can effect radical changes in this respect. For example, raising good yields of hay (not less than 50-60 centners per

hectare) consisting of a mixture of perennial leguminous plants and grasses, leads to an improvement in the physical properties of the soil, which is enriched with organic substances and acquires a good crumb structure. Crumb structure of the soil provides the best conditions for supplying wheat and other annual plants with nutriment and water. By growing perennial grasses and obtaining high yields of these grasses the farmer at the same time raises the fertility of the soil. Durum wheat sown after perennial grasses on land properly tilled, with plough and skim coulter, gives considerably higher yields than the same wheat sown on soft soils. The conditions of life for durum wheat are incomparably better on a field where perennial grasses have been grown, than on a field where they have not.

Further: it is now common knowledge that in the steppe regions, often prone to drought, the yields of cultivated plants are always higher on the fields protected by shelter belts than on open, unprotected fields. The life conditions for cultivated plants in the first case are considerably better than in the second. The beneficial influence of shelter belts on yields is indisputable.

Here is another example taken from the latest achievements of Soviet biological science. Some time ago Academician Lysenko proposed that

collective and state farms in the southern regions employ the method of planting potatoes in summer. The point of this measure is that when potatoes are planted the usual way in the south, in spring, they inevitably degenerate within three or four generations and cease to produce a yield. When, however, potatoes were planted on seed plots in summer, that is, two or three months later than usual, they no longer degenerated and began to give good seed material. The beneficial results of the summer plantings are so evident that this measure for growing seed potatoes is now incontestable.

All these irrefutable facts from agricultural practice that we have described have another extremely important aspect. No one doubts the fact that on a fertile field the yield is higher than on an unfertile one, or that potatoes do not degenerate if planted in summer. But will the reproductive qualities of grain of one and the same variety be different if gathered on a fertile and an unfertile field? Will the heredity, the breed, of wheat seeds change depending upon conditions of life, or, in other words, depending upon the size of the yield on the seed plot? Will the hereditary properties of seed potatoes be altered if the potatoes are planted on different dates? Biologists are not unanimous in their answers to these questions.

Some contemporary biologists who subscribe to the theories of the bourgeois scientists Weismann, Mendel, and Morgan believe that the breed of the seeds does not depend upon conditions of life and that hereditary properties do not change under their influence. They admit that one yield of one and the same variety of wheat on a fertile plot is higher than on an infertile one, but claim that the hereditary properties of the wheat seeds in both cases remain absolutely invariable. Michurin biology has proved that this assertion of bourgeois biologists is wrong.

Many agronomists have carried out the following experiment time and again. Wheat seeds, or seeds of any other plant of one and the same variety but grown under different conditions—on different plots, in different districts or in different years—have been sown on the same date and under similar, comparable conditions. In all the experiments the seeds belonging to the same variety but grown under different conditions regularly gave different yields. Investigations carried out by the Research Institute of Grain Husbandry of the South East, in the city of Saratov, have shown that winter wheats grown under different conditions (in different years) manifest a change even in such a hereditary property as winter hardiness. Experiments have shown that the productivity and other properties of seeds of

the same variety can undergo change due to conditions of life. The Mendelist-Morganists are forced to admit the fact that yields do change in such cases. But they interpret this fact in their own way. They say: true, there is a difference in the yields, but it is merely temporary and certainly not hereditary. Such a change—a modification, as they call it—has no relation whatever to hereditary changes. This interpretation of the Mendelist-Morganists is completely fallacious.

The followers of Michurin hold an entirely different view. It is true that if the above experiment with wheat be continued, that is, if the wheat is grown under the same conditions, then in one or two generations the differences in quality which the seeds manifested during the first year may level out. But this by no means signifies that the changes which the Mendelist-Morganists call modifications are in no way related to hereditary changes. In the course of the development of succeeding generations on the basis of small, "temporary," at times barely visible differences in the qualities of plants and animals, radical, deep, and permanent changes arise in a given species. If one and the same variety of wheat is grown for many years in regions with different environmental conditions then two varieties possessing definite and stable differences will at length be obtained.

All the varieties of cereals existing at the present time are the result of farmers' selection. The whole of the practical plant-breeding work carried on by farmers for centuries has been based on two methods—the altering of the conditions of life of the plant and the selection of the best plants for reproduction. Occasionally hybridization of several different forms of plants would occur in the fields independently of the farmer's intentions or actions. The hybrid material would be included in the selection and would increase its effectivity.

All field or garden plants that the farmer has ever raised are intended, primarily, for consumption. That is why he has always tried to raise plants the useful properties of which are most strongly developed. For example, if the market gardener raised cabbage he would do all he could to get the biggest cabbage heads possible. From among the good heads in his vegetable garden he would leave the very best for seed. It is by increasing the fertility of the soil, by improving its tillage and manuring, by obtaining, as a result, increased yields, and at the same time by selecting plants and animals, i.e., leaving the best specimens for seed and propagation, that man created all the highly-productive forms of agricultural plants and all the breeds of domestic animals that exist today.

In selecting the best plants and the best animals for breeding purposes the farmer did not formerly stop to think particularly about the causes of changes in breed. But these causes operated of themselves, independently of the farmer's intentions. Yet there is no doubt that these causes were created by the farmer himself in the course of solving his main problem—*that of obtaining a plant or animal with the most highly-developed useful properties*. The market gardener knew how to change conditions of life in order to obtain the largest heads of cabbage. By changing conditions of life he at the same time unconsciously created the constantly-operating causes of changes in the nature, in the heredity of plants. The process of variability evolved in the course of centuries, as a result of changes in the conditions of life created by man on the cultivated field where he raised his plants or in the cattle shed where he kept his domestic animals.

In our days it is imperative to accelerate to the utmost the processes which result in the emergence of desired forms of plants and animals. For this we must learn how to induce plants and animals rapidly to change their forms in the direction desired by man. Then among the altered forms it will be possible to select with greater success those that most fully correspond to the aim in view. The ability to make controlled

changes in the forms of plants and animals can be acquired only if we know the specific causes of variation in organisms.

Michurin founded the science that treats of the causes underlying the variability of heredity and the means of controlling variability. In our days Michurinist science is being successfully developed by Academician Lysenko.

Michurin and Lysenko clearly defined the tasks facing contemporary biology and established the basis on which it should develop. "Agronomy deals with living bodies—plants, animals and microorganisms," says Academician Lysenko. "A theoretical grounding in agronomy must, therefore, include knowledge of biological laws. And the more profoundly the science of biology reveals the laws of the life and development of living bodies, the more effective is the science of agronomy."

The study of the biological laws which the farmer and the animal breeder must learn to control is the basic task facing the contemporary science of biology which is being developed in the Soviet Union. Biological science will be able to solve this task only if it develops on the right principles, if the biologists hold a correct general view on the development of living nature.

The value of the Michurinist theory lies, first and foremost, in the fact that it teaches biologists how to approach the task of revealing the laws of the life and development of plants and animals.

MICHURIN AND HIS RESEARCHES

The world is now familiar with the name of Michurin, that remarkable Russian scientist—a man of iron will, strong character and great erudition.

The greater part of Michurin's life passed under the severe conditions of tsarist Russia. Before the historic year of 1917 Michurin was a lone figure in his scientific researches. He was, moreover, persecuted and harassed by the reactionaries in science and society. According to Michurin's own words he worked in complete isolation from society, without funds, without a reputation, waging a constant struggle against poverty. Michurin conducted all his researches out of the scanty funds he earned by his own labour.

However, his iron will was not broken by adversity. When the Great October Socialist Revolution took place he greeted it with joy, fired with creative power and dauntless daring. The great strength and steadfastness of his Russian

revolutionary spirit is typical of our people. It left its deep imprint on his strictly scientific theory which urges our biologists forward to reveal more fully the laws of living nature and to gain ever greater control over nature.

Ivan Vladimirovich Michurin's great merit is that he opened a new era in the development of biology, different from the entire previous history of this science. He used to say that the supreme mission of the biologist today *is not only to explain living nature, but to alter it in a planned and directed manner for the benefit of man.* In this is reflected the purport of Michurin's scientific work. It defines the nature of the principles and methods of his scientific and practical work.

The Soviet people have named Michurin the great remodeller of nature, a title he fully deserved since it corresponds with the truth. During his long lifetime he created more than three hundred different kinds of cultivated plants, most of them fruit and small-fruit cultures. A considerable number of them were bred by him in Soviet times. Not a single plant breeder in the entire world history of plant breeding had ever produced so great a number of varieties. This was due not only to Michurin's talent but also to the favourable conditions that were created after the Revolution.

Addressing the collective-farm peasantry Mi-

churin repeated time and again that "the collective farmer is an experimentist, and an experimentist is a remodeller of nature." As we see, Michurin himself called the collective farmers remodellers of nature. Thousands and tens of thousands of rank-and-file remodellers of nature worked with Michurin and actively helped him in his work.

In his tireless creative effort to remodel the plant world, in his striving to adapt the plant world to the needs of man in the best possible way, Michurin was guided by the aim of rendering the best and greatest assistance to the farmer who in his daily practical work transforms living nature.

In studying the laws of plant life Michurin never lost touch with reality. He linked all his scientific researches with practical work. This is what primarily explains the fact that while Michurin successfully solved many very important practical problems, he at the same time laid the foundation of the highly theoretical science which is today compelling scientists in all branches of biology to revise their obsolete methods of studying living nature and to work out new Michurinist methods. The Michurinist theory which is being elaborated in our country is raising our biological science to a new, higher level of development.

Lenin was the first to estimate correctly the value of Michurin's contribution to science. The civil war was still raging in the country when Lenin adopted radical measures to provide normal conditions for Michurin's work. For this purpose Lenin sent his closest assistants to the town of Kozlov, now Michurinsk, commissioning them to find out under what conditions the scientist was working and to do everything they could to provide him with all that was necessary for normal research.

In a letter to Michurin dated 1925, Kalinin wrote: "The further our Soviet Union develops and the stronger it grows, the clearer and greater will the significance of your achievements become in the general system of our country's economic life." With his profound knowledge of materialist philosophy, Kalinin already then saw the increasing significance and role of Michurin in biological science. Today the truth of Kalinin's words is self-evident.

In 1925, when Kalinin spoke of the future of Michurin's scientific achievements, the latter had only a few score followers, perhaps a few hundred Michurin-enthusiasts. With the development of our materialist science in the following years the ranks of the Michurinists greatly increased. Now they form a host that already includes many thousands of outstanding investi-

gators working in different branches of biology and agricultural science.

The sole aim of materialist biology as it is developing in the Soviet Union is to help the collective and state farms to solve the economic problems set by our Party and Government. Michurin's teachings provide the best ways of solving the agronomical problems now facing Soviet agronomists.

What is the essence of Michurin's works?

In characterizing the work of Michurin it is often said that he set himself the task of moving the South northward. In a general sense this is true. But Michurin himself was always more modest in formulating his tasks as a scientist and the aims of his scientific researches.

It was towards the end of the last century that Michurin became interested in fruit growing. In this connection he made a tour of many provinces in the central regions of Russia. All the orchards he visited made a bad impression on him, for he found there a very poor assortment of apples, pears, and small fruit.

The first task which Michurin set himself was to improve the assortment of the apples, pears, and small fruit cultivated in the central regions of Russia. His aim was to improve the quality of the varieties of fruit trees grown there, to raise their quality to the level of those in the

South. Later he added to this the difficult task of introducing into the central regions of our country such southern plants as grapes, apricots, peaches, etc.

After setting himself these concrete practical tasks Michurin raised the question as to whether these problems could be solved. In other words, whether besides the widespread Antonovka, Borovinka, Anis and other low quality varieties it was possible to introduce into cultivation in central Russia high-quality varieties in no way inferior to southern ones, whether it was possible to grow such southern plants as grapes, apricots and peaches in central Russia, for example at Kozlov, near Tambov.

In his consideration of this problem he gained much from practical farming.

At the end of the last century the cultivation of tomatoes in central Russia, not to mention the Moscow district, was a thing unknown. Tomatoes were raised only in southern Russia near Odessa, in Nikolaev and Kherson. To the market gardeners of central Russia the plant was completely unknown. Beginning with the present century the cultivation of this southern plant was extended to the North and now it has already become altogether commonplace in all vegetable gardens not only in the central belt, but even north of Moscow.

Michurin had still another example to guide him. The cultivation of sugar beet has been practised all in all about two or three hundred years. The ancestor of our present-day sugar beet grew in the wild state only along the coast of the Mediterranean Sea. It had a small woody root containing a very insignificant percentage of sugar. Wild beet was of little use for the extraction of sugar. When it became necessary for man to convert the wild beet into a cultivated plant, he did so. Moreover, he extended the cultivation of this plant of Mediterranean origin over a considerable territory. At present sugar beet can be grown much farther north than Moscow with a sugar content not of 5-7 per cent, but of 20-22 per cent and more.

Many facts can be cited from practical farming, which show the capacity of plants to spread over very extensive territories. Plants are capable of changing in the direction that man requires, in a direction that satisfies to an ever greater extent the demands man makes upon one or another of them.

Practical agriculture convinced Michurin that such southern plants as grapes, peaches and apricots can be moved from the South to the North and be made to bear normally in their new habitat. Yet the history of agriculture showed that the process of extending the cultivation of plants

from the South northwards often required scores of generations. The path of blind practice is a reliable but extremely slow one, requiring the work of many generations.

Michurin undertook considerably to accelerate the solution of this problem. He set himself the task of extending the cultivation of southern fruit plants to the North within his lifetime; and he found a practical solution for this problem. Thanks to Michurin, grapes and apricots grow and bear fruit not only in Michurinsk but also in the environs of Moscow.

Thus Michurin accelerated the extension of the cultivation of useful plants from one climatic district to another—a task which formerly required scores, hundreds, even thousands of years. At present the process can be still further speeded up by scientific means, with the help of the science which treats of the laws of development of living nature, with the help of the science that deals with the heredity and variability of plants.

There was no such science before Michurin. Before him, biology did not set itself the task of controlling the development of plants. At the close of the last century the outstanding Russian biologist K. A. Timiryazev said that control of plant development would be the watchword of the botany of the future. At the time Timiryazev was predicting this future, Michurin was al-

ready beginning his practical work to bring it about.

Before Michurin there was no science to help the farmer to gain practical control over the development and the alteration of the heredity of plants. Such a science had still to be created. That is why during the first stage of his work as a scientist Michurin groped, as it were, without having any clear idea of the scientific means of acclimatizing plants, without any idea of the scientific means of changing the nature of plants and adjusting them to new conditions of life. That is why mistakes were inevitable.

The life and scientific career of Michurin can be divided into three periods.

The first period was that of searches in other districts, chiefly southern ones, for already existing plant forms that could be cultivated under conditions prevailing in the town of Kozlov. During this first period the entire problem consisted in finding such forms and in transferring them to the new conditions of Kozlov.

The second period was that of mass-scale sowing of fruit seeds and of breeding new varieties of such cultures from seeds in Kozlov.

The third period was that of the directed alteration of the nature of plants, the conscious control of plant nature. This is the chief period in Michurin's career.

During the first period the task appeared to be as follows. If, for example, in the central regions of Russia there are no suitable varieties of apples and pears, then one must go south, select the most valuable varieties to be found there, obtain cuttings of these varieties, bring them to Kozlov and graft them on local stock. Michurin did a tremendous amount of work in this direction. However, after more than fifteen years of work he came to the conclusion, discouraging to himself personally but extremely important for the further development of biological science, that it was no use looking for ready-made varieties in other regions. *Varieties of agricultural plants must be created under the very same conditions in which they are to be cultivated for practical purposes.*

For example, it is impossible to create varieties of apple in Michurinsk and be certain that they will always be suitable for the conditions prevailing in the Moscow or any other region.

During the last years of his life Michurin was always reminding his followers that if they wished to make use of his achievements they must least of all base their work on already existing Michurin varieties. These varieties were created under the conditions prevailing in the Tambov Province and are best adapted to them. All agronomists and farmers who want to make use

of Michurin's achievements must study and master his methods and principles of work, and, in accordance with them, breed the required varieties in their own locality.

Michurin's postulate that conditions of life play a decisive role in forming varieties of cultivated plants was a fundamentally new dictum in science. Before Michurin many plant breeders were convinced that there can be cosmopolitan varieties, that is, varieties equally good for Arkhangelsk and Odessa, for Brest and Vladivostok, etc. Michurin was the first in science to prove that varieties of plants suitable for Odessa are not suitable for Moscow. This postulate of Michurin biology may be considered generally accepted now.

Michurin taught that varieties of agricultural plants must be created in the given locality, under the same conditions for which they are intended. In this connection, when, already in Soviet times, Michurin addressed plant breeders and collective-farm laboratory experimenters, he indicated that what is needed in every great undertaking is the collective thought of millions of people. He said that in the great work of remodelling the Soviet land the collective thought of millions is particularly necessary. In our times this collective thought has been created in the shape of an army of builders of collective-farm agriculture.

Michurin advised our plant breeders to work in cooperation with the front rankers of socialist agriculture. Since the latter deal directly with plants, they fully understand their nature and can offer effective help to the plant breeder engaged in producing new and better varieties, or in growing high-yielding seeds.

But let us return to the beginning of Michurin's researches. During the first period, Michurin, in his orchard in Kozlov, tested a great many high-quality varieties of apples and pears which he brought from other climatic districts. All of them, with rare exceptions, proved to be of no use under the conditions of Kozlov. Their chief shortcoming was their low winter hardiness.

After the failures of the first period, Michurin began to create new varieties in his own locality, in Kozlov—varieties adapted to local conditions. He started breeding new varieties of apple, pear, and small fruit from seeds. This marked the beginning of the second period of his researches. He gathered seeds in large quantities from different fruit trees of the best quality and sowed them in his orchard. From the large number of plants thus obtained he selected the best. This period of his work was crowned with considerable practical success. Michurin demonstrated that by sowing seeds it is possible to create new forms of fruit trees with high culture qualities, and

adapted to local conditions. Before Michurin began his researches the majority of fruit growers were of the opinion that only wild apple trees develop from the seeds of cultivated apples. Michurin by his practical work refuted this generally accepted view and proved that cultivated apples may be grown from seeds. At the same time he found the answer to the question why, when seeds of cultivated varieties are planted, the vast majority of seedlings obtained turn out to be wildings. This is due to the fact that, in the first place, cultivated apples are grown for practical purposes by grafting cuttings on wild stock. The roots of the wild stock exert a strong influence on the developing seeds of the cultivated apple. Secondly, when sowing seeds of cultivated apples, fruit growers pay little attention to the creation of conditions which contribute to the formation of culture characters. And in the given case this is of decisive significance.

From the mass sowing of seeds of cultivated fruit plants and the selection from the resulting plants of those which best answer the desired aims, Michurin passed on to the highest stage in his work, namely, that of controlling the development of plants. He undertook to alter the nature of plants in a given direction. This period is justly considered the chief one in Michurin's career. It is then that he created the greatest

number of varieties of fruit plants and elaborated the basic principles of his theory.

Later, proceeding from his experience of many years, Michurin divided plant breeding into two sharply distinct categories. The first type of plant breeding is based on chance findings. Such selection entails mass-scale sowing of a given species of plants and the selection of individual chance deviations that best correspond to the aim man sets himself. Such plant breeding is primitive. Man practised it even when the science of biology was only just coming into existence. The seed grower always selected the best plants for seed, the animal breeder the best animals for breeding.

By constant selection man, through the centuries, improved different forms of animals and agricultural plants.

Such work is extremely useful. Even in our times it must not be discarded. But selection in this manner requires much time. It is not based on the science of the development of living nature. Michurin, in this connection, wrote that even a complete ignoramus can sow at random scores of thousands of plants of a given variety and then select from them two or three specimens of the best type.

Neither Michurin nor his followers ever denied the worth of chance findings of useful forms

or of searches for these forms in the plant world. Such searches sometimes give good results. This is particularly true of the plants which are represented by numerous local, or so-called farmer's varieties—the results of many years of cultivation.

If no other ways of improving varieties are known, then it is better to apply the old method, namely, the selection of already existing forms from local sowing or planting material than to do nothing at all. That is how all the most widespread varieties of cereals were created in the recent past.

It is known that the widespread spring wheat Lutescens 062 was selected from an extensively used local farmers' variety of wheat Poltavka. When the plant breeder began to study the farmer-bred Poltavka he found the form now called Lutescens 062 already completely formed. The plant breeder merely selected from the Poltavka the plant that took his fancy and, made a study of its progeny, which he then reproduced. His selection proved to be useful work, and it gained him the respect of the Government and the people.

In former times all the varieties of cereals and other plants were bred by that method, viz., by the selection of completely formed types from the local seed material of the farmers.

Michurinists consider the method described above to be useful and correct. Even today they do not reject it. But this old method of selection, based on the search for random changes, does not always meet the demands of farming. For example, it cannot be applied when needed varieties are created from plants that but yesterday were wild forms, and are now being introduced into cultivation. To be more exact, if the plant breeder employs only the method of selection he will all his life be marking time or making little progress. It is, likewise, inexpedient to employ solely the selection method in creating southern types of plants for cultivation in the North. If one resorts simply to the old method of selection, both the introduction of wild plants into cultivation and the extension of southern plants to the North will require scores of years, centuries. That is why Michurinists, while not rejecting the search for already existing forms, strive to elucidate the ways by which these forms arise so as to be able to create consciously, according to plan and speedily, forms of plants that agriculture requires. And it is precisely Michurin's theory that opened the way to the elucidation of the process of how new forms are built and to the creation of desired forms according to plan.

Besides the primitive means of plant breeding, besides the selection of chance findings of

altered forms, there is, as Michurin said, another means of plant breeding, namely, *the deliberate alteration of plant forms, the alteration of the heredity of plants in a directed manner, the control of their nature.* Michurin laid the foundation for this means of plant breeding.

Michurin proved that the heredity of plants and animals is subject to change, that this variability is caused by conditions of life, i.e., the better the conditions of life the farmer creates for the plant in the field the better do the cultivated plants become from generation to generation. But the question as to what conditions of life can be considered the best for the plant is not so easy to answer. From the farmer's point of view the best conditions will be those which ensure the normal development of the plant and the fullest development of the properties which interest man. At the same time these conditions may not be the best for the biological properties of the plant. This is one of the most complicated problems of biological science, and the efforts of contemporary biologists should be concentrated on its elucidation. In such researches the Michurinist theory is an unexcelled guide.

Michurin was the first to demonstrate on a broad scale that plants acquire new breed qualities, new properties under the influence of new conditions of life. These new qualities are

inherited by the succeeding generations. Man can develop in plants properties and qualities which they hitherto did not possess but which are necessary to man.

We have already mentioned that in the recent past tomatoes could not grow normally, let alone ripen, when planted in the open under the conditions of the Moscow region. They had to be grown first in greenhouses and then planted out in the open. The "warm period" had to be artificially lengthened. But even under such cultivation, requiring so much labour, only an insignificant proportion of the fruits ripened normally before the morning frosts began in autumn. Yet the Gribovo Plant-Breeding Station near Moscow has already created varieties which do not require preliminary growing in greenhouses or under glass. These varieties can be planted out in the open in spring when work is begun in the vegetable garden, and toward the end of July or the beginning of August their fruits already ripen. The tomato varieties created at the Gribovo Plant-Breeding Station stand the conditions of cultivation in the open in the Moscow region—a capacity which has been developed by Michurinist plant breeders.

Nor did our market gardeners in the Moscow district know anything about the cultivation of eggplant 10 or 15 years ago. Guided

by Michurin's teachings the plant breeders of the Gribovo Plant-Breeding Station headed by Academician E. I. Ushakova have now created new forms of the eggplant which ripen in July-August. Formerly, if cultivated near Moscow, eggplant could not grow and produce ripe fruit. Now, as the result of skilful training, the plant has acquired this capacity. The eggplant has changed in accordance with its new conditions of life, in this case with those prevailing near Moscow.

The cultivated plants of today resemble their wild ancestors little if at all. They are adjusted to satisfy the requirements of man. For example, the fruits of the wild apple are small, sour, coarse and tasteless, and are of little use as food. The fruits of the cultivated apple are large, sweet, soft, and tasty. The root of the wild carrot is hard and small, whereas that of the cultivated carrot is large and delicate. The flowers of meadow plants are usually small and often insignificant, whereas the flowers growing in our gardens are large, beautiful and attractive.

How did cultivated plants, that are adjusted to the requirements of man, come into being? There is and can be no doubt that *cultivated plants originated from wild ones.* They did not drop ready-made from some other planet. They were created by man in the course of many

thousands of years of the development of agriculture. Man forced cultivated plants to change in the direction that satisfied his needs. By adapting plants to meet his needs he changed many plant forms so radically that today in a number of cases we cannot say from what wild plant the particular cultivated form originated. For example, to this day it has not been established what wild plant gave rise to our present-day wheat.

Michurin asked his opponents by what means man obtained his varieties of fruit plants. Not ready-made from other planets, he remarked sarcastically. All the varieties of fruit trees were obtained by sowing seeds and properly training young trees for many generations, and by selecting the best seedlings.

In the distant past the first step was precisely the sowing of seeds gathered from wild plants. Once the wild plants came under conditions of cultivation they were steadily perfected from generation to generation and, as a result of this process, have reached us in their present form.

How did people perfect the forms of cultivated plants? *Everywhere and always the first means has been the perfecting of the conditions of cultivation, the conditions of raising the plants.* By perfecting the conditions of the life of the plant the plant grower altered its properties and

characters accordingly. As the result of heredity the properties and characters that man needed were accumulated and fixed. This process of accumulation was accelerated by the selection of plants which possessed properties of interest to man in the most sharply expressed form. If a character or property appeared in the plants and man began selecting them from generation to generation according to this property or character, then variability would develop in the direction of selection. This is one of the laws of living nature.

A change in the conditions of cultivation of plants, a change in their conditions of life, everywhere and always served and still serves as the primary cause of the appearance of present-day cultivated plant forms.

This cause has been operating from the moment that man began to grow plants. In the tilled field, in the cultivated vegetable garden the husbandman placed the plants he was growing in conditions alien, not habitual, to them and thus forced them to change. Variability developed in correspondence with the new conditions and was increased due to the action of selection.

By tilling the soil and fertilizing it the husbandman changed the conditions of the supply of nutrition and water to the plant. As a result the cultivated plant acquired special needs. It is

very capricious, as they say. Today it can no longer grow on untilled and unmanured soil. And in the few cases that the cultivated plant can grow under such conditions it fails to produce the crop which man expects to get from it. The capriciousness of the cultivated plant arose as the result of man's growing it for ages on tilled and manured land. As the result of cultivation carrots acquired the capacity of producing large and delicate roots and at the same time developed what is called capriciousness. The same is true of other cultivated plants.

By choosing a given date for sowing or planting the cultivated plant man protects it from the inclemencies of weather, from pests and diseases, and changes all the conditions (as regards temperature, light, etc.) of the development of the plant. Everyone knows that in the central Russian belt it is best to sow early cereals (wheat, oats, barley) during the first 3-5 days of the spring sowing. Then they produce a better crop. Late sowing sharply decreases the yield, because the plants come under less favourable conditions of growth and development.

By tilling the soil, by weeding the fields, man protects the cultivated plants from their competitors in the struggle for moisture, food and light. We all know that if cultivated plants are not protected from weeds they will produce a

smaller harvest or perish altogether. Without man's help they are powerless to combat weeds. Such fragility and lack of independence evolved in the cultivated plants in the course of the age-long development of agriculture. This took place because man in his desire to obtain the products he needed placed the cultivated plants under conditions most favourable for the development of their capacity to give these products. In order to obtain an abundance of good grains from wheat the plant must be placed under conditions of good nutrition, it must be protected from all other species of plants and freed from the necessity of competing with other species of plants for food, moisture, light and other conditions of life. By creating good conditions for wheat the farmer unconsciously developed capriciousness in it.

By alternating the sowing of different species of plants on a given field man brings about changes in the grouping of the species of microorganisms that live in the soil and alters the nature of their activity. Myriads of microbes live and develop in the soil. The total weight of all the living microbes in the arable layer of earth amounts to many tons per hectare. One species of microbe is useful for one type of plant and harmful to another. The physical and chemical properties of the soil depend upon the activity of

the microorganisms. Under one type of rotation of different plant species in a field, the properties upon which fertility depends will be favourable for the plants raised, under another type of rotation they will be unfavourable. Under one the plant is protected against the attack of disease and pests, under another type it is placed in unfavourable conditions which lead to its succumbing to disease and pests.

After gathering the harvest, the farmer leaves part of it for seed. In order to obtain good yields one must know which seeds to leave for reproduction. But the yield properties of seeds depend upon the conditions under which the seed plants were raised. The size of the crop greatly depends upon the quality of seeds sown. And the quality of the seeds, in turn, depends upon the yield of the seed plants; as a rule, the higher the yield of the wheat or rye seed plants, the better the yield qualities of their seeds. As can be seen, here we have an indissoluble interconnection. The farmer by his practical work exerts an influence on the way in which these interconnections manifest themselves and on the results of the action of the laws that operate in living nature. The interconnections and laws with which man deals can, for the purpose of study, be divided into two groups: *the laws of heredity of plants and animals, and the laws*

governing their conditions of life. Michurin greatly contributed to the elucidation of the first group of laws. We have dealt with this briefly above. In disclosing the second group of laws much has been done by the Russian scientists Dokuchayev, Kostychev, and Williams.

THE SCIENCE OF CONTROLLING THE CONDITIONS OF LIFE OF PLANTS

When working indoors, in a greenhouse, under glass, the plant grower can control many of the conditions of life of the plant. He can regulate the moisture of the soil and air, the temperature of the air, light, the amount of carbon dioxide in the air, and the amount of nutritive substances in the soil. When growing plants in the field, on big areas, there are fewer facilities for controlling conditions of life as compared with indoors. But here, too, the plant breeder can still do very much. For example, by planting at the right date he can place the plants under the conditions of temperature, light and moisture that best meet their requirements. By properly spacing the plants he can create better conditions of illumination. The plant grower has complete control over the vernalization stage of plants. He can control

the conditions under which this stage passes in seeds that have just begun to germinate.

Very great possibilities for controlling conditions of life have been opened up to the plant grower through the achievements of our soil science. It is generally accepted that Russian soil scientists have accomplished very great successes in the study of soil. Russian soil science is the most advanced in the world. Dokuchayev and Kostychev were the founders of modern soil science. The elements of soil science that they elaborated were further developed by the outstanding Russian scientist V. R. Williams into a deeply theoretical science of the soil.

Vasili Robertovich Williams, the son of an engineer, was born in Moscow, on September 27, 1863. In 1883 Williams entered the Petrovskaya Agricultural and Sylvicultural Academy in Petrovsko-Razumovskoye. Due to the untimely death of his father, he suffered need and privation early in life, and while studying at the Academy had to work as a teacher in order to support his family. But despite these difficulties Williams was the best student in the Academy. He was proficient in all the sciences, but was particularly interested in chemistry and soil science. Williams' interest in these subjects attracted the attention of Professor A. A. Fadeyev who at that time lectured on soil science and agriculture at

the Petrovskaya Academy. In 1885 Professor Fadeyev offered Williams, a third-year student at that time, the position of assistant and assigned to him the work of organizing a research laboratory and superintending an experimental field. That year marked the beginning of Williams' scientific career.

Great events occurred in Russian agronomy during Williams' student years and the time of his first steps in science. In 1878 there appeared a remarkable book called *The Life of Plants* by Timiryazev, a professor of the Petrovskaya Academy. In 1883 Dokuchayev's fundamental work *Russian Chernozem* was published, in 1886 the classic work of Kostychev *The Soils of the Chernozem Region of Russia, Their Origin, Composition and Properties.* These works exercised a tremendous influence on young Williams. Dokuchayev and Kostychev were his teachers, and later he dedicated to them his chief fundamental work *Soil Science, Agriculture and the Elements of Soil Science* (1927)—the result of forty years of intensive research. The historical merit of V. V. Dokuchayev, wrote Williams, is that he made the genesis of soils the chief object of soil researches, that in place of the separate disconnected views on the process of soil formation and the factors that determine it, in place of the empirical study of separate properties of the soil he

created a theory which regards soil as a specific natural body that develops under the combined influence of five natural factors. Before Dokuchayev soil science was an empirical science; after the works of Dokuchayev it became a wide branch of natural history. From Williams' very first steps in science to the end of his life, soil science as a wide branch of natural history was the subject of his fruitful researches.

In 1887 Williams graduated from the Petrovskaya Academy. He finished the Academy with the clearly-defined aim of devoting all his work to the study of the soil, to the development of scientific soil research, the foundations of which were laid in those days by Dokuchayev and Kostychev. In 1887, the year he graduated, Williams completed his research entitled *A Study of Eight Soils of the Mamadysh Uyezd, Kazan Gubernia.* A short communication about the work was published in the "Proceedings of the Petrovskaya Agricultural and Sylvicultural Academy." Here Williams wrote:

"In general the problem of the influence that the inner properties of the soil exert on its fertility resolves itself into the following particular problems: 1) first of all, we must elucidate which properties of the soil, both chemical and physical, exert an influence on its fertility; 2) we must show what interdependence exists between the

different conditions that influence fertility; and 3) we must study to what extent they influence soil fertility depending upon the different combinations of these conditions." From the researches that followed one can see that the young scientist already in his first work determined in embryo the trend of his scientific studies of the soil, the aim of these investigations, and also the method of solving the problems raised. Williams was interested in the chief properties of the soil, and among them the most important—its fertility. From the very outset he decided to develop soil science from the point of view of solving the practical problems of increasing the yields of agricultural plants. But this aim required a natural-scientific approach to soil, it required that soil be studied in its development, it required a knowledge of the laws of soil development. Williams decided to study the conditions of soil fertility in their interconnection and interaction. A year later, in his work *A Description of the Method of Mechanical Soil Analysis Applied in the Agricultural Laboratories of the Petrovskaya Academy* Williams wrote about his method in soil science in the following terms: "In comparatively rare cases low soil fertility is caused by an insufficiency of nutritive substances, more often it is caused by an insufficiency of moisture, but

in the majority of cases by the poor physical properties of the soil.

"These last two factors interact, so that the qualitative and quantitative changes in one of them are inevitably reflected in the other." Later years saw a profound development in Williams' strictly scientific approach to the processes that take place in the soil, and this led him to accept dialectical materialism as a scientific world outlook. The ideas of Williams cited above were deep, fresh and fundamentally new in 1888-89. They threw light on the soil science of the future.

In order to elucidate the interaction of the conditions engendering soil fertility Williams at first —evidently under the influence of his teacher Professor Fadeyev—concentrated his attention on the study of the physical properties of the soil. He undertook a mechanical analysis of soil and in this connection worked hard to perfect its methods. In the course of these investigations Williams soon became convinced that all the physical properties of the soil depend upon the humus in it; already in the first works of the young scientist one can find indications of the discoveries which he made later, namely, that *the physics of the soil is determined by the biology of the soil, that the physics of the soil is determined by the activity of plants and microorganisms.*

In summing up the first period of his scientific

researches Williams wrote: "We have reason to believe that it is in the fine silt that all the nutritive substances of the soil available to the plant are contained, and also all the humus substances which they include.

"Due to the physical properties of the fine silt (and partly the medium silt) its presence has a very great influence on the binding qualities of the soil, and, since it contains all the humus compounds, the so-called structure of the soil and the durability of this structure depend upon the quality and quantity of the fine silt." (Williams, *Works,* Russ. ed., Vol. 1, p. 44.)

Williams very soon established the fact that the physical properties of the soil are very variable. He became interested in the factors that determine the physics of the soil. He was concerned not only with the actual structure of the soil but with the causes of the formation of the various concrete types of structure and their alteration in time and space. In his researches Williams always considered soil in its development. This distinguished the young soil scientist from all his precursors and contemporaries engaged in the study of soil physics. The desire to study the physical properties of the soil in development, the desire to disclose the causes of this development drew Williams more and more to the study of microbiology in general and microbiology of

the soil in particular. There is no doubt that the works of Kostychev on the microbiology of the soil exercised an exceptionally great influence on Williams. This influence explains an outwardly somewhat paradoxical fact in his career. In 1888 he was sent abroad for scientific studies. The young scientist, engaged though he was in studying the physical properties of the soil, did not go to the investigators who were studying this subject at that time, but to Pasteur with whom he began to study microbiology. At the same time he made a thorough study of the history of agronomy, the history of agriculture. In Williams' works the historical method becomes an obligatory, indispensable supplement to the experimental method. Williams devoted all his free time to a thorough study of practical agriculture, and this still further confirmed his view that all the conditions of soil fertility have to be studied in their historical development.

In 1889 Williams left France for Munich where he began to work in the laboratory of M. E. Wollny, a professor of agriculture and in those days an acknowledged authority on soil physics. Here Williams checked all the then existing methods of studying soil physics and came to the conclusion that, despite all its shortcomings, Professor Fadeyev's method was the best. In Munich he acquainted himself with the

state of soil science in Western Europe and became finally convinced that the pre-Dokuchayev soil science was empirical, not scientific. Real soil science begins with Dokuchayev.

After returning from his trip abroad in 1891 Williams began to lecture at the Petrovskaya Academy on general agriculture. At that time this course included the elements of soil science, general agriculture, plant breeding and the study of agricultural machinery. Together with his work as lecturer Williams carried on extensive researches. He summed up the results of his first years of investigation, made a critical survey of the state of soil science as a whole abroad, and mapped out the line of his further researches. This work was completed in 1893 in his Master's thesis "Investigations on the Mechanical Analysis of Soils."

In this work he made a remarkably deep, critical analysis of the unsoundness of the former, West-European trend in soil study which examined soil one-sidedly, either from the geological, physical, or chemical aspect. This trend was unsound because it was methodologically unscientific.

"The constant desire to reduce highly complex phenomena to some single cause and thus explain them still makes itself felt despite the fetters of exact science.... The followers of the old

chemical school try to reduce all the phenomena of agriculture to the chemical relationships between the plant and the soil. The followers of the more modern physical school ignore all other aspects of the problem and try to explain everything by the physical properties of the soil and their relations to the plants.

"The unsoundness of the chemical and the physical trends taken separately has forced many scientists to look for a way out of this indefinite state once again in a geological study of the soil." (Williams, *Works,* Vol. 1, p. 392.)

But neither the first, second nor third trend gave positive results because of their one-sidedness and narrowness. They failed to meet the demands of agriculture, they failed to explain the processes that take place in the soil. Voluminous scientific works "despite their youth have already become antiquated," Williams remarked.

Under the prevailing trend in soil science the chemistry of the soil was reduced to the chemistry of the parent rock minerals, while "soil physics simply became a science of dusts." (Williams, *Works,* Vol. 1, p. 203.) Under these conditions Williams, who set himself the task of developing soil science as a branch of natural history, of developing it along the lines of Dokuchayev and Kostychev, in many cases had to begin with a critical analysis of all that had been done before

his time, and to reinvestigate many problems pertaining to soil science.

Williams approached the task of developing soil science from the angle of the "relation of soil to agriculture," i.e., from the angle of production. And this required a strictly scientific approach, a many-sided analysis of the phenomena that take place in the soil. The old soil science was far from raising such a problem. In the old soil science a tendency prevailed to find some one, given feature that could serve as an index of soil fertility. It is easy to see that such a tendency was the embodiment of the metaphysical way of thinking. It found particularly precise expression in Liebig's mineral theory. This theory is very simple: the chemical analysis of plants is to show what the plant contains, what food it requires; the chemical analysis of the soil is to show what the latter lacks; a comparison of the results of the first analysis with those of the second will give an answer as to how soil fertility is to be raised. The solution of this problem seems quite simple. "And so, hundreds and thousands of analyses follow one after the other; the soil is analyzed, manures are analyzed, animals and parts of animals are analyzed, plants and parts of plants are analyzed, and all this is done to find out what is taken from the soil and what should be returned to it." (Williams, *Works,* Vol. I,

p. 390.) What was the result of all these endless analyses? They did not help agriculture to raise the fertility of the soil. "Millions of money were buried in the soil, and yet it continued to give poor yields . . ." he wrote. (*Ibid.*) The failure of all these attempts can be easily understood. "Fertility of the soil is the derivative of a number of its properties and of the relation between it and the agents of plant life. It is quite obvious that, being the result of such a complex interaction of the most diverse causes, fertility cannot manifest itself in some one property of the soil." (*Ibid.*, p. 104.) Only an all-round study of the interaction of all conditions can give us an idea of what fertility is.

Williams disclosed the highly complex interconnections which operate in soil. Already during the first years of his work he established the fact that a change in the physical properties of the soil leads to a change in its chemical properties and to an alteration in the conditions of the supply of water to the plants. Changes may also take place in reverse order. Changes in chemical properties of soil may lead to a change in the physical properties of the soil and to changes in the supply of water to the plants. The structure of the soil and the durability of this structure may change and lead to changes in the conditions of the supply of water and minerals to the

plants, and in the fertility of the soil. There is reason to believe that the following chain of alterations is also possible, namely, that with a change in the amount of water in the soil a change takes place in the chemistry of the soil, then in the physical properties of the soil, etc.

But where is the main link which could serve as the point of departure in disclosing the interconnections in the highly complex chain of causal relations as regards the properties of the soil? Williams established that *the main link is the activity of plants and microorganisms which determines the development of the soil, the variability of all its properties and, above all, that of its chief property—fertility,* which distinguishes soil from barren rock. Williams did not deal with these principal causes in his work "Investigations on the Mechanical Analysis of Soils." At that time he was studying them, but considered it untimely to publish his results. It is these researches that he had in mind when he wrote: "In this article I present only a small part of my research. . . ." This side of the matter was dealt with in greater detail in his introductory remarks before defending his thesis (on January 31, 1894). Here he raised the question of the relative roles of analysis and synthesis in scientific research and came to the conclusion that although analysis is absolutely necessary and obligatory,

research cannot be considered complete unless it is concluded by a summarized synthesis. Together with the solution of this problem he clearly defined his general view on soil.

"Are physiological chemistry, anatomy, and histology necessary for the study and development of physiology? Of course, they are. There can be no doubt of that. They are needed in order to dismember, to reduce to their separate parts, to study and analyze a number of the simpler, more elementary parts and phenomena that go to make up the life and development of the complex living organism and the living organism itself.

"But is not soil also an organism, can one really consider as nonliving, in the strict sense of the word, this complex combination of mineral and organic substances which is never, not for a single moment, in the state of rest, which is permeated through and through with life and living beings, which itself gives rise to life and in which the state of rest and immobility signifies death?" (Williams, *Works,* Vol. 1, pp. 77-78.)

Both the physical and the chemical analyses of the soil are needed. But neither the one nor the other taken separately, nor both together, can solve the problem of soil fertility, still less the problem of the development of fertility, of the development of soils. This evolution can be understood only if we study soil as a developing, inte-

gral whole governed by the activity of plant and animal organisms. We cannot imagine either the origin or the formation of soil without the direct participation of plants, said Williams in his first course of lectures on soil science which he read at the Petrovskaya Academy in the nineties of the last century.

Plant physiology is the principal basis of all the deductions and conclusions of agricultural science, wrote Williams in his dissertation. In parenthesis it should be noted that by plant physiology Williams meant the physiology of higher and lower plants, that which is known in contemporary terminology as plant physiology and microbiology. Here Williams laid the initial bases of biological soil science. To the elaboration of these fundamental principles Williams devoted the next decades of his creative activity. By regarding the humus substances in the soil as products of the activity of microorganisms he upheld the researches of Kostychev in the field of soil microbiology.

P. A. Kostychev established that the strength of the bonds of the nitrogen and the mineral substances in the humus and their low accessibility to the plant are explained by the fact that these substances are not free, but are incorporated in the bacteria and fungi in the soil. The majority of scientists tried to disprove this view. Williams

resolutely defended it and proved that Kostychev's ideas were being more and more fully confirmed. This confirmation was supplied first and foremost by the researches of Williams himself who at that time came to the notable conclusion that unless the riddle of soil humus be solved, "we shall remain slaves of this substance, and agriculture will not be able to do anything new. And soil science will not emerge from the state of a skilfully drawn plan of the future until the *chemistry of the soil* is transformed into *soil physiology.*" (Williams, *Works,* Vol. 1, p. 222.)

In order to study the physiology of the soil Williams began to work on the sewage farm that was organized to serve the city of Moscow. Williams devoted fifteen years of his life to this work, at first in the capacity of organizer of this farm and later as head of the agricultural department at the Lublino sewage farm. The materials relating to this period show that here he worked both as a soil biologist and as an agricultural organizer and economist. During these years he formulated his profoundly scientific conclusions: "Scientific agriculture is the application of the natural and economic sciences to the elucidation of phenomena in agriculture as a branch of industry.

"In no other sphere are these two branches of science interwoven so closely and are so entan-

gled that the true cause of a phenomenon is often completely masked due to the interference of the numerous conditions under which it manifests itself." (Williams, *Works,* Vol. 1, p. 393.) Economic conditions determine the usefulness of a given agrotechnical measure. The more an agrotechnical measure coheres with a deep understanding of the facts of nature the more successfully does it stand the test of economic conditions. Economic conditions here play the role of practice which serves as a criterion of truth. Williams applied this criterion of truth in his work on the sewage farm.

He transformed the farm into a big industrial laboratory where he made an all-round study of problems relating to the biology of the soil. This work found its expression in two new researches carried on over a period of many years and developed along the same agrobiological lines.

In 1903 Williams began an experiment, conducted for the first time in the history of science with lysimeters. It was undertaken to study the humic acids in the soil. On an open plot near the laboratory in the Petrovskaya Academy, 10 concrete chambers were built in the ground. Each one of them was filled with 16 tons of some particular type of soil, and on this soil he created a vegetal cover for each chamber. In all the soils in the

lysimeters natural conditions were maintained for the anaerobic and aerobic processes of the decomposition of organic residue by bacteria and fungi. (Anaerobic processes occur where there is a shortage of free oxygen, aerobic—where there is free access of oxygen.) The anaerobic process took place in peat soil. The aerobic process proceeded rapidly in structured flood-land clay. The fungous process developed in the lysimeters where the vegetal cover was represented by forest. The entire amount of water drawn from each lysimeter by drain pipes was subjected to exact measurement every day all the year round and immediately passed through a bacteriological filter—different one for each lysimeter. After filtration the water was evaporated and the sediment collected, dissolved in water and subjected to fractional crystallization. In the course of his fourteen years' work Williams managed to educe in crystalline form a number of soil organic acids. He accumulated them in considerable quantities and studied their properties and the conditions under which they are formed, depending upon the plant formation growing on the given soil. He investigated the part played by these acids in the physical and chemical processes that take place in the soil, the role of these acids in the creation of a particular physical structure of the soil, and

in the creation of various conditions of nutrition for the plants.

Almost simultaneously with his study of the organic substances of the soil, Williams began extensive researches into the biological features of grasses and leguminous herbs. In 1904 he laid out a nursery for these plants at the Petrovskaya Academy. Here he gathered a collection of perennial grasses unequalled anywhere in the world. It contained up to 3,000 different species, races, and forms of grasses and leguminous herbs. In the nursery Williams studied the biology of the grasses, the interrelation between the grasses and the soil, and thereby deepened his extensive observations of meadows made during his numerous expeditions to different parts of our country. There is no doubt that Williams was a specialist of world standing as regards the properties and biological features of grasses. The vast number of observations of meadow grasses made over the whole area of our country, combined with the data on the biology of grasses that he obtained in his nursery, served Williams as the basis for his theory of meadow cultivation and the science of meadows. But what is most important, knowledge of the biology of grasses served Williams as an integral part of the scientific foundation on which rest his materialistic teachings about soil.

Work on the sewage farm, his experiment with the lysimeters, and the experience gained in the nursery of perennial grasses and leguminous herbs brought Williams to his radical conclusion concerning the essence of the soil-forming process, concerning the essence of what he called soil physiology—the department of soil science which he himself elaborated.

In 1914-16, Williams published the first edition of his fundamental work *Soil Science* in which he summed up the vast body of material that he had accumulated during the preceding decades of his research work. In this book he put forward for the first time in comprehensive form his theory of the universal soil-forming process. In 1920, a considerably supplemented and revised second edition made its appearance. In 1920, Williams published the first part of his *General Agriculture* followed, in 1922, by the second part. Here he expounded the conclusions which may be drawn for agriculture from his teachings about soil science. In the same books he treats of the principles of the travopolye system of farming. In 1927, Williams published a new fundamental work *General Agriculture and the Elements of Soil Science* in which he gives his final version of the theory of the universal soil-forming process and the travopolye system of farming based on it. Beginning with the fourth edition, Wil-

liams re-named this work *Soil Science. General Agriculture and the Elements of Soil Science,* thus stressing the fact that the theory of soil serves as the basis for agricultural science.

The essence of Williams' theory of the universal soil-forming process is that under the influence of thermal and chemical factors the rock massif that appears on the surface of the earth is weathered and disintegrates. As a result of the weathering marl is formed. Marl is not soil as yet; it possesses only the rudiments of an essential property of soil, namely, fertility. Marl is called *soil-forming rock* or *parent rock*. The weathering process, the destruction of the rock cannot bring about the formation of soil. In nature, simultaneously with the process of weathering, which creates the parent rock, there takes place, interweaving with it, *the soil-forming process*, which determines the course and the rate of the entire process, including the weathering of rock. The soil-forming process is a *process resulting from the activity of plant and animal organisms*, a *process involving the influence of plants, animals and microorganisms on the parent rock*. In all parts of the world two different elements go to make up the soil-forming process, namely, the process of the creation

and the process of the destruction of organic substance. The nature of the soil-forming process depends upon the conditions under which it proceeds—where it takes place and how long the process takes. But despite the definite differences in the nature of this process in various parts of the globe, its determining cause is everywhere the activity of plants, animals and microorganisms. S o i l i s a d e r i v a t i v e o f l i f e— such is one of the basic principles established by Williams. This principle reflects the essence of his theory of the universal soil-forming process.

A second essential aspect of Williams' teachings is the theory of the minor, biological cycle of substances. The biological process of the synthesis of organic substance and the biological process of the breakdown of organic substance which constitute the essence of the soil-forming process are inseparably interconnected and, taken together, go to make up the minor, biological cycle of the plants' mineral and nitrogenous nutriment. This biological cycle takes place on a part of the curve described by the big, geological cycle of substances in nature.

The pattern of the geological cycle, according to Williams, is as follows. Water is constantly being evaporated from the surface of the ocean; it returns to dry land in the form of rain, penetrates the soil-forming parent rock, dissolves all

that is soluble in it and carries the dissolved substances back to the ocean via the rivers. Part of the elements of plant food thus carried away are consumed by the plankton of the sea which serves as food for fish. These elements are then again partially returned to the soil in the shape of the fish caught by birds, animals, and man. But the greater part of the food elements of plants remains in the sea.

Obviously, soil must possess the capacity of retaining and thus concentrating the food elements of plants. This is accomplished by *the biological cycle* which proceeds in the opposite direction to the geological cycle. The water-soluble elements of plant food that accumulate in the soil-forming rock are assimilated by plants and bacteria, and in this way are transformed into organic substance. The organic substance does not dissolve in water, and consequently is not washed out into the rivers, is not carried to the ocean but leads to the accumulation of nutritive substances in the soil. The farther the soil-forming process proceeds the greater the surplus of humus created in the soil. The continuous alternation of the building up and the breaking down of organic substance, which constitutes the essence of the soil-forming process, leads to an increase of the reserve of bound potential energy on the earth. In his investigations on soil formation

Williams established that the shape of the curve described by the biological cycle is that of a progressively expanding spiral determined by the progressive development of the forms in which life manifests itself on the surface of the earth. The more life there is in a given part of the globe the higher is its general fertility, the greater is the reserve of food there. All the objective laws of nature indicate that man is capable of infinitely increasing soil fertility. One of Williams' greatest scientific achievements is his elaboration of this part of contemporary soil science. On the surface of the globe one may find many easily distinguishable types of soils. There are the podzols, the peat soils, the chestnut soils, the red and the chernozem soils, saline and acid soils. According to Williams all these soils are different stages of a universal soil-forming process. But here the question naturally arises, why are soils different? Williams' teachings about the universal soil-forming process answer this. The great chernozems of our country and the turf-podzol soils of the non-chernozem parts of our land are the different stages of a single process. The difference between them is primarily due to the difference in the duration of the soil-forming process. The South was freed of the ice of the last ice age earlier than the central

belt, so that the *absolute age* of the chernozem soils is greater than that of the podzol soils. In the places where we now find chernozem the plant associations have exerted their action on the parent rock for a longer period of time and accumulated greater amounts of humus in the soil. *The absolute age of the chernozems is greater than that of the podzol soils.*

But even within one zone we find different kinds of soil, namely, soils with greater or lesser amounts of humus. These differences are not caused by time, but by the conditions under which, and the place where, the soil is formed. For example, if the soil-forming rocks contained much calcium there is more humus in the soil. The soils of valleys (in the turf-podzol zone) contain more humus than the soils of watersheds. The differences that arise due to the conditions and the place where the soils are formed were defined by Williams as the *relative age of the soils*. *But in all cases the leading factor in soil formation is the activity of plants and of the world of microorganisms that lives in symbiotic relations with the plants.* If the soil of today were to be cleared of plants for a number of years it would rapidly lose its fertility and become barren dust.

The conclusions that Williams arrived at after studying the process of soil formation, the theory of soil formation, served him as the scientific basis for the elaboration of the travopolye system of farming. This system is the crowning glory of Williams' scientific work, it is a synthesis of all the achievements of progressive agricultural science. The travopolye system of farming is a complex of measures and includes the theories of reclaiming the soil and augmenting its fertility, of soil cultivation, manuring and the organization of agricultural areas—theories that are interconnected with each other.

Lea crop rotations ensure the restoration and augmentation of soil *fertility*. According to Williams' theory of the universal soil-forming process, fertility is the chief property of soil, the property that distinguishes it from marl which is infertile for agricultural plants. Fertility is determined by the ability of the soil to furnish plants during their entire life span with the requisite quantity of water and food elements. As Williams established, durable crumb structure is the basis of soil fertility. Only on structured soil are plants provided with sufficient water, air and nutritive substances throughout their entire life span, the water being firmly retained inside the crumbs while the air passes between them. That is why structured soil possesses high fertility and en-

sures good yields. The structure of the soil is created by the roots of perennial grasses. That is why the lea crop rotations necessarily include the cultivation of perennial grasses. It is absolutely necessary to cultivate a mixture of perennial leguminous plants (clover, alfalfa, and others) and perennial grasses (timothy grass, wheat grass and others). The roots of the perennial grasses penetrate into the soil, divide it into crumbs and enrich it with active humus which provides for good soil structure by pasting together the small crumbs of soil. Dispersed, structureless soil is transformed into crumby, structured soil. At the present level of agronomical science no method of creating durable soil structure is more perfect than that of introducing the right crop rotations of leguminous plants and grass mixtures. It should be always remembered that *perennial grasses have a beneficial effect on soil only when there is a good* crop of them (not less than 40-50 centners of hay per hectare). The structure of the soil is improved by the roots of perennial leguminous plants and grasses. But there will be sufficient roots in the soil only if the grass stand is good.

However, it is not enough simply to raise a good harvest of perennial grasses. The land after the grasses must be properly cultivated. This aspect of the problem is dealt with in the theory

of the system of soil cultivation. The soil must be tilled with plough and skim coulter. The correct organization of the agricultural area is of great significance. The watersheds should be covered with water-protecting forests, the fields shielded by shelter belts, and the ravines afforested. The correct distribution of water-protecting forests and shelter belts in combination with other elements of the travopolye system—sowing of perennial grass mixtures, the right system of soil tillage and others—makes it possible to regulate the conditions of fertility and ensure high, stable yields.

The travopolye system of farming is a system of agronomical measures which not only increases the productivity of agricultural plants, but improves the soil itself. It provides for measures that exert an active influence on all the conditions of the life and development of plants and microorganisms. Williams demonstrated that if coordinated and simultaneous influence be exerted on all the factors of life of agricultural plants there is no limit to the increase of yields that may be obtained. He proved the utter unsoundness of the so-called "law of diminishing returns" put forward by bourgeois science and long since refuted by Lenin.

Only under socialism, which opens boundless horizons for the development of the productive

forces in agriculture, can the travopolye system of farming be completely mastered and, what is more, mastered in a very short historical period. Under capitalism it is impossible to master the correct system of agronomic measures, and capitalist progress in agriculture is inevitably linked with the exhaustion of the soil, with the degeneration of valuable agricultural plants.

That yields do increase continuously if all the component parts of the travopolye system of farming are mastered has been convincingly proved by the practical work of the collective and state farms where Williams' theory has been a guide to action. Williams' teachings served as the basis for the great program of agricultural development contained in the decision of the Council of Ministers of the U.S.S.R. and the Central Committee of the Communist Party of the Soviet Union adopted in 1948 on the initiative of J. V. Stalin, and entitled "The Plan for the Planting of Shelter Belts, Introduction of Lea Crop Rotations and Building of Ponds and Reservoirs in Order to Ensure High and Stable Harvests in the Steppe and Forest-Steppe Areas of the European Part of the U.S.S.R." This decision has been lovingly named by the people the Stalin plan of remodelling nature. The Stalin plan provides for the subjugation of the elemental forces of nature to the will of man. It is a plan to

defeat drought, a plan to obtain high and stable yields. Contemporary agrobiological science is capable of helping agriculture in the solution of these problems.

Williams created a profoundly scientific agronomic theory which has been incorporated as a component part into Michurin agrobiology. The remarkable feature of this theory is that it has opened the way to ever new victories of the human mind in gaining knowledge of the laws governing the development of plants. Williams' theory is valuable, primarily, because it points out to agrobiologists the correct, scientific, creative trend in the study of living nature. At present this theory is being successfully developed by Soviet scientists headed by Academician Lysenko. In his article "On the Agronomic Theory of V. R. Williams" (*Pravda,* July 15, 1950) Academician Lysenko wrote: "One may truly say that V. R. Williams' theory of the laws of soil development and fertility is the theoretical basis for controlling the nature of soil fertility in agriculture."

The further materialist agrobiology advances, the more will it reveal the laws governing the biological cycle of substances, and correspondingly, the more will it enable man to control the process by which conditions of life are formed on earth. The Stalin plan of remodelling the steppes

of the southeast is the greatest plan in the history of mankind for intervening in the random course of nature's development and for the deliberate extension of the biological cycle.

* * *

The scientific deductions and suggestions of V. R. Williams are now being put into practice on a mass scale in agricultural production. With the solution of the problems that face agriculture today, Williams' agronomic theory continues to be developed and perfected. At the same time, it is being cleared of obsolete and, in some cases, erroneous propositions, and is thus becoming still more scientific and effective.

Academician Lysenko indicates: "While giving due credit to the positive, progressive theoretical basis of the travopolye system of farming, it should also be noted that V. R. Williams' teachings about the travopolye system contain a number of erroneous propositions which, in the interests of science and practical farming, must be subjected to criticism." In this article a criticism is made of Williams' negative attitude to the cultivation of winter cereals, his erroneous recommendation that grass fields be ploughed *everywhere*, irrespective of climatic conditions, only in late autumn, his assertion that drainage is

inexpedient as a means of combating soil salination, his mistakes in appraising certain agricultural implements (roller, harrow), and of his claim that it is unprofitable to apply mineral manures on structureless soils. Clearing William's agrobiological teachings of erroneous postulates and creatively developing the basic principles of this theory will help to make it more effective and profound.

By constantly linking up their theoretical researches with the solution of practical agricultural problems, Soviet agrobiologists are perfecting the theory of contemporary agrobiological science, and continuing to develop further Michurinist agrobiology, the elements of which were elaborated by Dokuchayev, Kostychev, Michurin and Williams.

DEVELOPMENT OF THE MICHURINIST THEORY IN OUR DAYS

Michurin elaborated the basic principles of the materialist theory of heredity and its variability. Dokuchayev, Kostychev and Williams worked out the basic principles of the materialist theory of controlling the conditions of life of plants. It is on this basis that we are now successfully developing Michurinist agrobiology.

What is agrobiology? The elucidation of the causes of different concrete phenomena, which the farmer must and wishes to control, is the fundamental task of agrobiology. "In order to have the required amount of different plants and animals in practical farming," writes Lysenko, "it is extremely important that agrobiological science understand the complicated biological interrelations and regularities of plant and animal life and development. This is necessary in order to be able in the best way, with the greatest benefit to man to provide the necessary conditions of life for the required plants and to protect them from all normally occurring biological and climatic inclemencies." (T. D. Lysenko, *Agrobiology*, Selkhozgiz, 1949, Russ. ed., p. 531.)

In these words are reflected the main principles of contemporary agrobiology as a science. Agrobiologists study the laws of living nature with a view to its practical alteration in the interests of man. For example, they study the regularities of the plant's mineral nutrition in order to utilize correctly organic and mineral manures in feeding plants. They investigate what changes occur in the nature of plants as the result of different ways of feeding them so as to create hereditarily altered plants that make best use of the conditions of life that man provides for them. They study the results of the influence

of the plant's activity upon its habitat in order to make this habitat best suited for the plant itself. Agrobiologists study the causes of the processes that take place in the fields in order to eliminate the causes of low yields of cultivated plants and to augment the action of those which engender high yields of useful plants. If potatoes are planted in the South in spring the new young tubers are formed in the summer under conditions of high temperature. Lysenko has proved that high temperatures lead to the degeneration of potatoes and to the reduction of their yield qualities. If potatoes are planted in summer the young tubers are formed in autumn when the temperature of the air and the soil is lower than in summer. The tubers that are formed under autumn temperatures are not degenerate, but healthy and highly productive.

The core of agrobiology is the theory of heredity and its variability. The basic problem of scientific agriculture, the basis for the development of agricultural science is the study of the requirements of plant organisms. The revealing of the requirements of organisms, the study of the causes of the emergence and the development of these requirements, the study of how different plants react to the influence of the environment is "the basis of the theoretical work of our Soviet science of he-

r e d i t y and its v a r i a b i l i t y," writes T. D. Lysenko. The Michurinist science of heredity serves as the theoretical basis of agrobiological science as a whole—a science which is being successfully developed by Soviet scientists.

How do Michurinists approach the study of the phenomena of heredity? In order to gain knowledge of these phenomena they, first and foremost, study the r e q u i r e m e n t s o f a g i v e n s p e c i e s o f p l a n t s a s r e g a r d s c o n d i t i o n s o f l i f e. These requirements are extremely diverse. Some plants require field conditions, others must grow in meadows. Some plants prefer marshes, others cannot stand such conditions. Drain a marsh and the vegetation on that area will be sharply altered. Anyone who has had to do with living nature knows these facts.

But Lysenko discovered that the r e q u i r e m e n t s o f p l a n t s a s r e g a r d s c o n d i t i o n s o f l i f e are different at different periods of their individual lives. At every stage the developing plant requires its own specific conditions of life. For example, winter wheat and winter rye require low temperatures (1 or 2°C.) during their first stage of development (the vernalization stage) and are indifferent to light. The vernalization stage is of varying duration—from 10-15 to 60-70 days and more—in different species of

plants and in different varieties of one and the same species (for example, wheat). After the vernalization stage is completed the plant acquires new qualities. At the same time its demands upon conditions of life change. The second developmental stage—the photo phase—sets in. During this stage winter wheat already requires a high temperature (as compared with that of the first stage) and a long day. If these requirements are not met the plant will fail to traverse its photo stage and will be incapable of passing on to the next stage of development.

The researches of physiologists have shown that the requirements of plants in respect to conditions of mineral nutrition are different at different stages of development.

The activity of the green leaf is also different at the different stages of development. The biochemical processes that take place in the leaf when the plant is passing through the vernalization stage are altogether different from those that take place in the leaf of the same plant after it has completed its vernalization stage.

A knowledge of the requirements of plants as regards conditions of life at different stages of development makes it possible to control their development, to control their lives. If winter wheat at the first stage of its development is not given low temperatures it will not pass on to

the next stage of development; as a result earing will fail to take place and seeds will not be formed. If the winter plant from the first hours of its growth is kept continuously under temperatures of not less than 15 to 20° C. it will remain in the grass phase for many months and will not develop, will produce neither stem nor spike. If the plant of the same winter wheat is placed under short-day conditions after its demands for low temperature have been satisfied, its development will also be retarded.

Knowledge of the demands made by plants on conditions of life, knowledge of the biology of plants is the theoretical basis of all the departments of agronomic science. A concrete knowledge of the demands made by plants upon conditions of life serves as the basis for altering these demands, for altering the heredity of plants. Proceeding from the theory of the phasic development of plants, Lysenko elaborated the teachings about the directed alteration of the nature of plants. By means of scientifically-based experiments he proved that the alteration of heredity is forced as a result of the incongruity between the demands of the plants and the existing conditions of life. Heredity changes in correspondence with the conditions of

life that have been brought to bear on and assimilated by the organism.

Let us cite the following concrete example.

In the winter wheat Lutescens 0329 the first (vernalization) stage lasts 50-55 days. This variety requires low temperatures (1 or 2° C.) for a period of 50-55 days. If Lutescens 0329 plants develop under these temperatures for the given number of days they will normally complete their vernalization stage and pass on to the next stage. If the course of all the succeeding stages is normal, the plants will produce seeds with unaltered—winter—breed qualities.

If the plants of the winter wheat Lutescens 0329 are constantly kept from the first hours of their growth under conditions of high temperature (over 15° C.) they will grow but fail to traverse the vernalization phase; they will remain at the tillering phase, fail to produce stems, and as we already know, will not ear and, consequently, will produce no seeds.

Thus if we supply the normal conditions that the plant requires (the first case), the heredity of the plant is not altered. If, on the other hand, we fail altogether to meet the requirements of the plant (the second case) it will not traverse its vernalization stage, will not develop or produce seeds and, consequently, here, too, we fail to alter the nature of the plant.

How then must one treat the plant to force its heredity to change? For this it is required that the vernalization process begin under normal conditions, but be completed under conditions abnormal for the given breed of plants. To do this, winter wheat Lutescens 0329 must develop during the first 40-45 days under normal low temperatures (from 1 to 2°) and then be placed under conditions of a higher temperature (from 10 to 15°). In the experiment described the vernalization process in the plants is initiated and develops under normal conditions. At the end of the process the normal conditions are replaced by such as are not habitual for winter plants. As a result the vernalization process, once initiated, is after some delay nevertheless completed. After the first stage the succeeding ones develop, and the plant produces seeds.

As numerous experiments have shown, the completion of the developmental process of winter wheat under abnormal conditions breaks down the old heredity, breaks down the old requirements as regards conditions of life and creates in the plants an inclination to develop under the same conditions as those in which the process was completed (in other words, to traverse the vernalization stage at a temperature from 10 to 15° C.). Plants that are grown from the altered seeds produce offspring with an

unstable heredity. By skilfully training such plants a stable spring form may be obtained in the course of three to four generations.

The theory of phasic development opened the way to the directed alteration of the heredity of plants. The means of effecting this was elaborated and made concrete following the alteration of winter into spring plants and spring into winter ones. However, other properties and characters of plants may likewise be altered. The theory of the directed alteration of heredity in plants indicates *when, how and to what conditions of life the developing plants must be subjected* in order to break down its old heredity and to create a new one that corresponds to the conditions of life which we bring to bear upon the organism.

The question as to whether it is possible to alter the heredity of plants in a given direction is one of the principal issues over which a long struggle has been waged between Michurinists and anti-Michurinists. Michurinists adduce theoretical and practical proof that this is possible whereas the anti-Michurinists categorically deny it. We shall return to this important question later and deal with it in greater detail.

The theory of phasic development has made it possible to provide a theoretical and practical solution of the question so important to science,

the one concerning *the possibility of altering the heredity of plants in a directed manner.* Proceeding from this theory Lysenko solved a number of other problems that are extremely important for the science of biology and for practical agriculture. For example, on the basis of the theory of the phasic development of plants the causes of the degeneration of potatoes in the South were disclosed and a method elaborated for planting potatoes in summer, thus helping combat the degeneration of seed potatoes in the arid steppe districts. We have already mentioned this measure. The same theory has made it possible to shorten the developmental cycle of cereals grown in the fields (the well-known vernalization method) and, in this way, to combat the harmful influence of dry winds and, consequently, raise the yields. The theory of the phasic development of plants has proved to be a sound scientific basis for the hybridization of plants and the alteration of their nature in a directed manner by means of training.

This theory has opened up a scientific and fruitful path for an investigation of the laws of plant life and development.

The new way of treating the problem of heredity and its variability has made it possible to present the practical problems of seed growing in a different light.

The old pre-Michurinist biology maintained that the task of the seed grower is to reproduce the variety bred by the plant breeder.

Michurinist biology maintains that the task of the seed grower is to raise highly-productive seeds and in this way to perfect the different forms of cultivated plants from generation to generation. "The end result of plant breeding we take to be the obtaining of seeds, and seeds we call the sowing material which will give qualitatively and quantitatively the best harvest in the particular district served by the plant breeder," writes Lysenko. "Practical farmers are right," he continues, "when they say: for us, practical workers, the main thing is not the division of selected seeds into first-, second-, third-rate ones, etc. What interests us, first and foremost, is the high productivity and good qualities of seeds. That is what we need." (Lysenko, *Agrobiology,* p. 126.)

The anti-Michurinists have always asserted that the hereditary properties of pure-line varieties are immutable whereas Michurinists have proved that heredity is subject to change and that it can be controlled. One of the control levers is hybridization. Hybrid seeds are more productive and more viable than non-hybrid ones. By means of the hybridization and correct training of seed plants it is possible from generation

to generation to improve the breed of cereals, to develop new qualities in them that more and more fully meet the requirements of man. As we already know, these laws were for the first time established by Michurin. Supported by the theory of the phasic development of plants, Lysenko further elaborated the scientific basis of hybridization laid down by Michurin.

The anti-Michurinists have been assiduously trying "to confine Michurin to his orchard," to impress upon the minds of people that the laws Michurin established hold good only for fruit plants. T. D. Lysenko defeated this attempt. His researches on annual plants have proved that Michurin's theory is a theory of general biological significance. He disclosed and is further developing the *main principle of Michurin's theory—that of altering the nature of plants in a directed manner, including hybridization as a means of such alteration.*

In order to obtain new economically valuable, viable and productive forms by means of hybridization, the scientist must know how to make a correct choice of the parental organisms and, after crossing, how to train the hybrid plants correctly.

The postulate that *it is possible to train hybrid plants* must be especially

stressed. It is not hybridization taken by itself, but the p r o b l e m o f t r a i n i n g h y b r i d (and non hybrid) o r g a n i s m s that has been the subject of controversy for many years in biological science, the subject of the struggle between the two trends—the Michurinist trend, based on the teachings of Michurin, and the Weismannist trend which originated from the teachings of the bourgeois biologists Weismann, Mendel and Morgan.

We consider it necessary to dwell especially on the Michurinist theory of hybridization.

MICHURIN'S THEORY OF HYBRIDIZATION

The theory of hybridization is one of the central points in Michurin's general biological theory. And that is natural! Hybridization will always be of great significance in controlling living nature. If hybridization is properly applied it will accelerate the process of creating new forms of plants and animals useful and necessary to man.

The seeds taken from the wild forest apple, wrote Michurin, may be sown in thousands, in millions, the young trees may be carefully reared, but one cannot possibly expect to obtain cultivated seedlings—not even one or two of them—from such a sowing in the f i r s t g e n e r a-

tion. Only after many generations will the improving influence of cultivation make itself manifest in the forest wilding.

To transform the wild apple into the cultivated apple of today fruit growers spent years and years of work raising many generations of apple and developing the properties of the cultivated form in the wild one. These properties, as the result of heredity, were accumulated in the course of a long series of generations. And present-day plant growers, as Michurin remarked, do not as a rule have to "go over old generations." (Michurin, *Selected Works,* Eng. ed., Moscow 1950, p. 23.) Due to the property of heredity that plants and animals possess, contemporary plant and animal breeders are able to make use of the results attained by their ancestors in the course of many generations. One of the means of accomplishing this is hybridization. With the help of hybridization man can combine the hereditary bases of two (and more) initial forms with the aim of creating the desired forms. The solution of the very difficult problems of hybridization requires an exact biological theory. Michurin laid the foundation of this theory. Lysenko further developed and deepened the Michurinist theory of hybridization. This development was accomplished through the practical solution of the

problem of creating varieties of cereals within a given period according to plan, through the practical application of the broadly-known method of intra- and intervarietal hybridization as a means of improving varieties of self-pollinating plants (wheat, barley and others), and through the use of the methods of the seed growing of cross pollinators (rye, maize and others). In connection with those researches T. D. Lysenko noted that "a profound Michurinist understanding and study of the problem of hybridization and of the fertilization of plants in general is extremely important for the practical work of our socialist agriculture." (Lysenko, *Agrobiology,* p. 311.)

Hybridization is an essential part of the Michurinist way of controlling the nature of plant and animal organisms, the means of inducing this nature to change in the direction required by socialist practical farming, a change brought about, as Lysenko says, through controlling conditions of life, that is, through physiology. Particularly great significance is attached to the elaboration of the theory of hybridization under present-day conditions when it has been proved that the "inheritance of characters acquired by plants and animals in the process of their development is possible and necessary." (*The Situation in Biological Science,* Eng. ed., Moscow

1949, p. 20.) Only in the light of the general biological law formulated by materialist biology is it possible fruitfully to investigate and solve the problem of hybridization.

The fruitful employment of the hybridization method is inconceivable without the acceptance of the Michurinist theory that the directed alteration of heredity is possible, is inconceivable without the Michurinist theory of training. Lysenko's well-known book *Heredity and Its Variability* ends with the following words: "By means of skilful hybridization, by combining breeds in the sexual way it is possible to combine at once in one organism all that has been concentrated, assimilated and fixed from nonliving in living matter for many generations. *But no hybridization will give favourable results unless conditions are created that promote the development of the different qualities which it is desired for the variety being bred or improved to inherit.*" (Lysenko, *Agrobiology*, p. 522. Emphasis ours.—*V. S.*)

This conclusion expresses the basic principle of the Michurinist theory of hybridization. Michurinist hybridization always necessarily presupposes the training of hybrid plants as the decisive measure. By means of training, hybrids acquire new properties, new characters, such as did not exist in either of the parental forms taken for the cross.

The Michurinist theory of hybridization allows for the appearance of new qualities and characters in hybrids which neither of the parental forms possessed, and for the inheritance of these characters in the succeeding generations.

In biology there exist two fundamentally opposite systems of views on hybridization—the Mendelist-Morganist conception, and the Michurinist conception.

The creators—as well as the adherents—of each of these theoretical systems assess in different ways the *significance,* the *purpose* of hybridization and their approach to the *study* of the problem of hybridization is different. Underlying each system of views is a fundamentally different solution of the problem concerning the character of man's interrelations with living nature, his environment. The Mendelist-Morganist system of theoretical views is based on a contemplative attitude toward the secrets of living nature, on the passive registration of phenomena and the belief that man's power of learning the secrets of living nature is limited, and still more so his capacity to control living nature. The Mendelist-Morganist theory is divorced from life, from practical work.

The Michurinist theory is constantly linked with life, with practice. The Michurinist system of views on hybridization is based on an active

attitude of man towards nature—the attitude of one who sets out to remodel it. Man, wrote Michurin, has always intervened and continues to intervene in the actions of nature. It is imperative to do so in order to disclose her secrets. It is on this basis that science develops and that our knowledge, which by its nature is limitless, becomes deeper.

Mendelism-Morganism proceeds from the complete repudiation of the possibility of controlling the behaviour of hybrid plants. The Mendelist-Morganists regard hybridization as a means of mechanically combining two forms of plants (or animals) and obtaining a third form as a result of such combination.

The Mendelists regard hybridization as a means of mechanically combining properties and characters of the parental forms taken for the cross in a third form. Their line of argument is approximately as follows: supposing a given plant is of perennial habit, while another type of plant gives a good crop of seeds. Let us cross these two and combine their properties in one hybrid. The hybrid will inherit from one parental form the perennial habit and from the other the capacity for producing a good yield of seeds. According to the Mendelist-Morganists it is from such a summation that a valuable plant—a perennial cereal—will be obtained. They act

accordingly. They cross two organisms and expect accidentally to find among the hybrid offspring the desired type of hybrid, one that arose by itself. Their expectations of accidentally finding valuable forms usually come to nought and the undertaking is abandoned.

The entire "theory" of hybridization put forward by the Mendelist-Morganists can be reduced to the following extremely simple and lifeless scheme.

Two parental forms are crossed and the first hybrid generation is raised. The first hybrid generation will show which of the two parental forms is dominant, in other words, which heredity (the paternal or maternal) prevails. In the second hybrid generation segregation will take place, some of the offspring resembling the maternal form, others—the paternal. The experimenter can count the number and the kind of offspring obtained. In the third generation some of the offspring will continue to segregate and some will prove to be constant, will not segregate. The experimenter is again able to count how many offspring segregate and how many do not, how many segregants resemble the paternal form and how many the maternal. The result of the counts can be expressed in the form of a ratio, while among the hybrid forms raised a practically useful one may be found accidentally.

This simple scheme reflects the entire essence of the Mendelist-Morganist "science" of hybridization, although as the Mendelist-Morganists expound it, their theory of hybridization outwardly seems incomparably more complicated. But their complicated verbiage does not make their "science" of hybridization a real one. It lacks the basic features of a science, namely, *it does not make it possible to predict, and, what is most important, to control the behaviour of hybrid progeny.* According to Mendelism-Morganism, in the first and the succeeding generations the dominance of one heredity over the other is, as it were, determined by fate, it cannot be changed or controlled. The phenomenon of segregation in the second generation is also, as it were, determined by fate, because the nature of segregation is predetermined, it can neither be changed nor controlled. The researcher is doomed to look for chance findings of the desired combination which, however, possesses nothing new as compared with what the two initial parental forms possessed.

The Michurinist approach, the Michurinist theory of hybridization is fundamentally different.

Michurin never lost sight of the obvious circumstance that in hybridization two hereditary bases of two parental forms are combined. As the

result of this union the hybrid plant possesses greater potentialities of adapting itself to conditions of life than either of the parental forms taken separately. But it is not only and not so much in this union that Michurinists see the main aim of hybridization.

In evaluating the role of hybridization in the creation of the plant varieties we require, Michurin especially stressed the point that by means of hybridization we can accelerate variability in the direction that man desires. According to Michurin, hybridization destabilizes the organism, makes it more plastic, more sensitive to alterations in conditions of life. As a result of this sensitivity, properties and characters often appear in the hybrid organism which neither of the parental forms possessed. If the plant breeder knows how to supply the hybrid plant with the corresponding conditions of life he may be able to create the desired form.

Michurin and his followers regard hybridization as a source of variability of plant forms, as a source of entirely new properties in the hybrids. The new properties appear in hybrids due to the greater sensitivity of the latter to conditions of life. The new properties appear in hybrids as the result of their assimilating new conditions of life.

Wherein lies the potency of the Michurinist science of hybridization? In the fact that it cor-

rectly understands the property of heredity which all plants and animals possess.

Michurin said that crossing two different forms of plants or animals is simple enough. It can be done even by one unversed in the science of biology. The difficulty lies in obtaining forms from the cross which are desirable and necessary for agriculture. Here is where a sound biological science is needed. The foundation for such a science was laid by Michurin.

The Michurinist science of hybridization attributes prime importance to the skilful choice of parental forms for the cross. Before crossing *it is necessary to choose the parental forms skilfully.* They must be so chosen as to obtain from the cross hybrids with the desired properties. With this in mind it is essential to make a thorough study, as fully as the contemporary level of science permits, of the biological properties of the parental forms, their past, their conditions of development. We must ascertain under what conditions of life the different characters and properties that interest man developed in these plant forms and to what conditions of life they are adapted. Only after an all-round study and a well-grounded choice of parental forms can the cross be effected and the hybrid seeds obtained. As Michurin showed, it is a matter of consequence what flower on the chosen plant one takes for

fertilization. Some flowers give better hybrids, others on the same plant give less successful ones.

Obtaining the hybrid seeds does not as yet solve the problem. "After skilfully created hybrid seeds are obtained," writes Lysenko, "it is absolutely necessary skilfully to raise plants from these seeds." (Preface to the *Works* of I. V. Michurin, Russ. ed., 1948, Vol. 1, pp. IX-X.)

Hybrid seeds grown under different conditions give rise to plants possessing different economic properties and qualities. "By providing relatively definite external conditions at a definite time Michurin altered and directed the individual development of plants." (*Ibid.*, p. X.)

Michurin demonstrated experimentally and proved that every hybrid develops those properties of the parental forms, the development of which is favoured by external conditions from the very first stages of the hybrid's growth. If, for example, one parental form is highly winter-hardy and if this property is determined by good conditions for weathering the plant in the autumn (a long, dry, sunny autumn), then the hybrid will develop the same property only under the same favourable conditions of weathering.

Michurin established that the farther apart as regards place of origin are the pairs of parental plants, the more distant they are in respect to ha-

bitat, the easier is it to control the behaviour of the hybrids and to obtain the required forms. For example, if we cross a maternal plant adapted to local conditions with another plant not adapted to local conditions then in the hybrid generation the properties and characters of the maternal plant will be dominant. If, however, both parental plants are equally little adapted to local conditions there will be no such dominance and it will be easier to control the development of desirable qualities in the hybrid plant. Greater success is gained in training such hybrid offspring.

From the great number of methods that Michurin elaborated for training hybrid seedlings the mentor method may be cited as an example. With the help of the mentor method Michurin succeeded in turning the development of hybrids in the desired direction. By crossing the first-rate American winter variety of apple Yellow Bellefleur with our orchard Kitaika he obtained a new variety with excellent flavour and large fruits. Michurin named it Bellefleur-Kitaika. The first fruits of the hybrid ripened in the middle of August and kept in storage only up to the first half of September. Michurin considered this early ripening to be a very great shortcoming in the new variety, so he decided to eliminate it. For this purpose he grafted a few cuttings of the maternal plant Yellow Bellefleur into the crown of the new

hybrid variety. The grafted cuttings served as mentors. After the grafting, "beginning with the very next fruiting," wrote Michurin, "the time of ripening receded gradually to a later date, until finally the fruits kept in winter storage until January." (Michurin, *Selected Works,* p. 214.)

Much data may be found in Michurin's works on the results of the training of hybrid plants carried out along scientific lines. By means of training, the great remodeller of nature moulded the requisite forms of fruit plants; he removed undesirable properties and characters and developed, accentuated desirable and useful ones.

Michurin *founded the science of training plants and controlling plant development. This is the main point in Michurin's teachings.* He attached exceptionally great importance to the alteration and the control of the nature of plants by means of training (including the mentor method). That is the main point in the Michurinist theory, and it is this that called forth "the greatest number of objections on the part of geneticists and plant breeders of the Mendelist-Morganist trend," writes Lysenko. (Preface to the *Works* of I. V. Michurin, Vol. 1, p. XII.)

Michurin's theory of training proceeds from the fact that *the heredity of plants can be changed by bringing conditions of life to bear upon them,* that heredity may be altered in a directed manner,

that properties acquired by plants in the process of their directed alteration are inherited, are accumulated in a series of generations. The ability of plants and animals to inherit the characters and properties that the organism acquired in the course of its development is one of the fundamental principles of Michurin's theory of training. The Weismannist-Morganists repudiate this law of living nature.

The difference of opinion between the Michurinists and the Weismannists (Mendelist-Morganists) arises from the fact that they are guided by different world outlooks and, consequently, answer certain fundamental questions of biology in different ways. Here we shall mention four of these questions, the answers to which most clearly show the difference between the Michurinists and the Weismannists. They are as follows:

First, is the heredity of plants subject to change or not? Is man capable of altering the heredity of plants and animals?

Second, if heredity is subject to change then what are the forces that call forth this variability? Is man capable of disclosing these forces, of disclosing the causes of the variability of heredity, and, after elucidating them, can he control variability?

These two questions can be reduced to the third and more general question of whether plants

and animals are capable of acquiring new properties, new characters and transmitting them by heredity?

The answer to these three questions depends upon the answer to the last and most important question: what are the interrelations between the organism and its conditions of life? If heredity is subject to change, wherein lies the original cause of this variability—within the body of the organism itself or in the conditions of its life?

Let us examine the questions raised.

IS THE HEREDITY OF PLANTS AND ANIMALS SUBJECT TO CHANGE OR NOT?

The answer given by the Weismannists to the question of whether heredity of plants and animals is changeable or not, is that the heredity of plants and animals remains unchanged unless two organisms differing from each other are crossed (hybridized). Man is incapable of altering heredity. The views of the Weismannists on this question are clearly expounded by a foreign scientist, E. Schrödinger, in his book *What Is Life? The Physical Aspect of the Living Cell.* In this book the author raises the question: "What degree of permanence do we encounter in hereditary properties and what must we therefore attribute to the material structures which carry them?" He

gives the following characteristic answer which fully accords with the essence of Weismannism: "The answer to this can really be given without any special investigation. The mere fact that we speak of hereditary properties indicates that we recognize the permanence to be almost absolute."

The statement that the permanence is almost absolute puts the matter in a nutshell. Schrödinger illustrates the "permanence" of heredity by a graphic example. He writes that several members of the Hapsburg dynasty in the XIX century had the same "peculiar lip disfigurement" as members of that dynasty in the XVI century. Thus according to Schrödinger who borrowed his assertion from contemporary Weismannists "the material gene structure, responsible for the abnormal feature, has been carried on from generation to generation through the centuries, faithfully reproduced at every one of the not very numerous cell divisions that lie between."

The theory of the constancy of pure lines is based on the complete denial of the variability of heredity. According to this theory the progeny of a self-pollinating plant (for example, wheat, barley, oats) are not subject to variation. Such progeny can remain unchanged for centuries. Variation results only after crossing (hybridization) one form of self-pollinating plant with another which differs from the first in one way or another.

Let us take for example the already mentioned pure-line variety of winter wheat Lutescens 0329. At one time the plant breeder found a single specimen in the peasant crops and reproduced it. It is from this plant that this variety originated. At present Lutescens 0329 is sown on considerable areas in different parts of the Soviet Union.

From 3 to 4 million plants grow on one hectare of land. The Weismannists hold that as regards their heredity, all of them are exactly alike, since they arose from one plant. At present the winter wheat Lutescens 0329 is sown in many districts of the Soviet Union such as the Volga district, the Urals, Siberia, etc. The Weismannists maintain that the heredity of the wheat, regardless of where it is cultivated, whether it be grown in Saratov or Omsk, is everywhere the same. Every practical farmer clearly sees the fallacy of such a view.

The variety Lutescens 0329 is a winter one. If we accept the Weismannist point of view then we shall have to maintain that this form of wheat everywhere and always was and will be of winter habit. Yet it has been experimentally proved now that under the influence of definite, specially created external conditions, the winter wheat Lutescens 0329 may be converted into a spring form.

The Weismannists consider the constancy of pure lines of self-pollinating plants to be so abso-

lute that, according to them, it is useless to select the best plants in pure lines. They say that when pure varieties are sown it is of no consequence what plants, what seeds are taken for the next sowing. Whether we take the best plants or the worst ones, whether we take the biggest and heaviest seeds or the smallest and lightest ones of a given breed, the heredity of the succeeding generations will remain the same, it will be constant.

In 1935, Academician Lysenko opposed the theory of the constancy of pure lines. He said: "Self-pollinating varieties—pure lines—when cultivated for a long time, change and, consequently, often deteriorate, degenerate. Anyone who knows anything about tomatoes is aware of the fact, first, that they are self-pollinators, and second, that if a good variety be cultivated without selecting the best plants for seeds they degenerate already after 3-5 years. This is very noticeable with the tomato because the plant is easily altered, besides people make greater demands on this culture and any change in the form of the fruit or the ripening date is immediately noticed." (Lysenko, *Agrobiology*, p. 191.)

The same may be said of wheat, oats, barley and other self-pollinating plants. Possibly, changes in the varietal qualities of these plants are noticed not quite so soon as in tomatoes, nevertheless this phenomenon does take place.

It will be detected sooner or later in the mentioned varieties.

Academician Lysenko and his colleagues have proved by numerous experiments that pure-line varieties are subject to variation. Several million plants growing on one hectare must in some way differ from each other because they develop under different conditions. Their sex cells must differ somewhat, too. How can this difference be made manifest? The way to do it has been elaborated by Lysenko, who has shown that if hybridization of wheat plants is effected within a variety (under the conditions of free pollination) the resulting seeds possess greater productivity and are more resistant to all kinds of inclemencies. As regards vigour and development, seeds from intravarietal crosses possess all the properties of hybrid seeds. On this is based the method of intravarietal crosses of self-pollinators proposed by Lysenko in 1935 as a means of improving pure-line varieties. If all the plants of the pure-line variety were absolutely alike in their hereditary properties, as the Weismannists maintain, then the phenomenon of hybrid vigour in plants would, naturally, not make itself manifest.

The Weismannists at one time vigorously opposed Lysenko's proposal about intravarietal crossing. Their objections were unconvincing and wrong and now they have been completely refut-

ed by practical farming and by scientific experiment. Numerous experiments carried out by many researchers have shown that the wheat seeds obtained as the result of intravarietal crossing give 2, 3 and 4 centners of grain per hectare more than ordinary seeds. This hybrid vigour is preserved for a number of generations.

The theory of the constancy of pure lines has also been refuted by the now well-known fact that skilful, systematic selection of the best plants within a pure line of wheat or barley grown on very fertile fields leads to the improvement of the breed qualities of seeds, to variation in the pure line.

Finally, the numerous experiments on the directed conversion of winter into spring plants and vice versa that have been repeated after Lysenko by many investigators conclusively shattered the antiscientific postulate about the constancy of pure lines.

The Weismannists were literally incapable of openly defending the proposition of the immutability of heredity. Although they continued to hold their old unscientific views, they began to admit the possibility of variability. But since they still failed to understand the main point in Michurin's teachings their admission did not improve their standing in science, nor did it make their views more correct. The controversy between Michurinists and anti-Michurinists centred

around the following question: If heredity is subject to change, then what are the forces that cause this change? Is man capable of disclosing these forces and controlling them?

THE CAUSES OF THE VARIABILITY OF HEREDITY

The gist of the Weismannist view as to whether man is capable of disclosing the forces that cause variability of heredity and of controlling them is quite simple.

If heredity does change, say the Weismannists, it does so due to some cause, whatever it may be, only not to conditions of life.

If the Weismannists were right, then man would never be able to disclose the causes underlying changes in heredity. Weismannists actually maintain that the causes of changes in heredity are unknowable.

They assert that changes in heredity have no past history. What does that mean? It means that every change in heredity occurs suddenly, fortuitously.

The qualitative change that arises is not preceded by quantitative change. That is the only way one can interpret the assertion of the Weismannists that "all new alterations in the organism which as yet have no past history" should be

regarded as hereditary, indefinite changes. This assertion is scientifically wrong.

Phenomena that have no preceding history are purely fortuitous, causeless events. There are no such phenomena in nature. And yet the Weismannists class changes in heredity among such causeless phenomena. This can be confirmed by their own words. For example, a certain Weismannist wrote in his book: "The appearance of individual mutations (hereditary changes—*V.S.*) is by all indications a case of chance phenomena. We can neither predict nor deliberately induce this or that mutation. So far it has been found impossible to establish any casual connection between the quality of mutation and definite changes in the factors of the environment."

From such a general postulate it is quite legitimate to draw a conclusion that has a bearing on the practical activity of man. If hereditary changes (mutations) have no past history then there is no reason, indeed, no necessity, for the biologist to search for the causes of heredity changes. If in nature heredity changes suddenly, unexpectedly, fortuitously, then there is no reason for, no possibility of, looking for the underlying cause through the agency of which desired changes could be induced. All the experimenter can do is look for methods of treatment which call forth sudden, chance alterations. Today the

Weismannists consider strong electric discharges and poisons (colchicine) to be such agencies. To-morrow, perhaps, some other means will be included in the list.

By acting upon an organism with chance agencies one can, most certainly, alter its heredity. For example, by acting upon the plant with the poison colchicine the structure of the nucleus in the cell is changed. Among the organisms altered with the aid of colchicine it is possible to find an interesting form by chance. But that will truly be only a rare and fortuitous finding.

Michurin regarded searches for useful changes, which relied only on good luck, as treasure hunts. To reckon on a chance find of a useful form of plant or animal means abandoning the idea of disclosing the natural laws of form building; it disarms the biologist in his study of the laws governing the development of living nature. It is perfectly obvious that the prospect of never knowing the laws of biology, and in particular the causes that underlie changes in heredity, and reliance on chance cannot be regarded as the general road of development of materialist biology.

The founders of Marxism-Leninism have long ago explained the origin of "sudden" phenomena in society and in nature. Every sudden, unexpected phenomenon in nature, said Lenin, is just

as sudden and unexpected as the birth of a child nine months after its conception.

Weismannists by their assertions about the suddenness of hereditary changes repudiate the existence of causes inducing changes in heredity. This is tantamount to repudiating biological science as such.

If a true investigator, particularly a biologist, wishes to understand the nature of a phenomenon he must, as fully as the level of science permits, gain an understanding of the embryonic period, so to speak, that precedes the visible change, the appearance of the new form. It is particularly incumbent upon the investigator to gain knowledge of the embryonic period of a phenomenon if he studies it for the purpose of gaining control over it. That is why investigators who follow the Michurinist trend are interested in the laws governing the development of changes, are interested in the conditions and the causes of the appearance of visible changes. They concentrate their efforts on the study of the conditions leading to the emergence of visible changes, on the study of the process of the disappearance of old and the emergence of new properties in plants and animals. Only such an approach can be considered scientific.

The antiscientific assertion concerning the unknowability of the causes underlying the variabil-

ity of heredity, the antiscientific assertion that all hereditary changes are due to chance without a preceding historical process prevent the investigator from learning to understand the laws of form building in living nature, they doom the biologist to the passive contemplation of that which takes place. This is not characteristic of true science, and particularly of such a science as materialist biology.

"The Morganist-Mendelists, who proclaim that hereditary alterations, or 'mutations' as they are called, are 'indefinite,' presume that such alterations *cannot as a matter of principle be predicted.* We have here a peculiar conception of unknowability; its name is idealism in biology.

"The assertion that variation is 'indefinite' raises a barrier to scientific prediction, thereby handicapping practical agriculture," said Academician Lysenko in his report at the session of the Lenin Academy of Agricultural Sciences of the U.S.S.R. in 1948.

The great biologist of our times I. V. Michurin by scientific researches and practical achievements unprecedented in the history of plant breeding, laid the foundation for a new stage in the development of materialist biology.

The antiscientific postulates of the Weismannists about the unknowability of the causes of variability and their denial that it is possible to in-

duce directed changes in the nature of plants and animals were countered by Michurin's profound scientific principle that man can disclose the causes of variability in the nature of organisms, that he can on this basis control variability and create according to plan forms of plants and animals useful to man, that he can create them better than nature does spontaneously.

The great significance of Michurin for contemporary biology consists in that he demonstrated how progress along the path of perfecting cultivated plants and domestic animals can and must be accelerated. "It is possible with man's intervention," wrote Michurin, "to *force* any form of animal or plant *to change more quickly and in a direction desirable to man.* There opens before man a broad field of activity of the greatest value to him." (I. V. Michurin, *Works*, Russ. ed., Vol. IV, p. 72.)

Michurin demonstrated that man can control the heredity of plant and animal organisms by changing their conditions of life. Michurin's investigations refute the basic postulate of the Weismannists that hereditary properties are independent of the conditions of life of the plant or animal. The conditions of life are the cause of all the changes in the heredity of plants and animals.

Michurinists are studying ever more thoroughly how conditions of life alter heredity and are

gaining ever greater control over this variability. We shall acquaint the reader with one of the numerous facts accumulated by Michurinists in this domain.

We have already referred above to the conversion of a winter plant into a spring one and vice versa. There we had to do with alterations within one species of soft wheat. Now we shall speak of the alteration of the nature of one plant species into that of another. It is much more difficult to gain control over the regularities of such alterations than over those that occur within one species. It was not without reason that Michurin pointed to the great difficulty of venturing beyond the species, beyond specific forms.

It is widely known that durum wheat differs considerably from soft wheat. The two belong to different wheat species. They differ in external characters, in the quality of grain and in their requirements as regards conditions of life.

Those who have had to do with the sowing of durum wheat know that often one may find in the crops a small number of soft wheat plants. Seed growers are annually forced to weed the crops of durum wheat so as to clear them of soft wheat admixtures. Plant breeders and seed growers have long been puzzled as to the source of these admixtures. Many of the more observant investigators have long supposed that the durum wheat

species can be converted into another species, i.e., into soft wheat. At present the possibility of such transformation has been experimentally proved. It has been proved that under the influence of conditions of life not habitual to it durum wheat is converted into soft wheat.

It is known that there are no real winter forms of durum wheat. All durum wheats are spring plants. The work carried out in recent years under Lysenko's leadership has made it clear why this is so. It is enough to sow spring durum wheat for several generations late in autumn for it to be converted into soft winter wheat. Changes in the conditions of life radically change an organism's heredity.

Man is capable of altering the conditions of life of plants and animals. By changing conditions of life we can alter heredity. This has been proved by Michurinists. True, as yet, we know very little about how conditions of life should be changed so as to alter heredity in the direction we need. We still know very little as to when altered conditions of life are to be brought to bear on the developing organism in order to change its hereditary properties. But there can be no doubt that the more our materialist Michurinist biology develops the more knowledge will be gained about this most important aspect of the science which treats of the development of living nature. To

Michurinists it is an indisputable fact that "the world and its laws are fully knowable, that our knowledge of the laws of nature, tested by experiment and practice, is authentic knowledge having the validity of objective truth, and that there are no things in the world which are unknowable, but only things which are still not known but which will be disclosed and made known by the efforts of science and practice." (J. Stalin, *Dialectical and Historical Materialism*, Eng. ed., Moscow 1952, pp. 21-22.)

The most dangerous thing for the development of biological science was that up to quite recently antiscientific convictions were widely current about the causes underlying the variability of heredity being unknowable. These convictions were spread by reactionary biologists, by the Weismannists.

Of exceptionally great significance for the entire future development of our biology is the fact that the Michurinists have been able to prove experimentally the possibility of discovering the causes underlying the variability of heredity and of controlling this variability, that they have been able to deal a crushing blow to the Weismannists and their fallacious assertions about the unknowability of the causes of hereditary changes.

Of equal significance is the exposure of another antiscientific, idealistic proposition of the

Weismannists, namely, that the properties acquired by plants and animals in the course of their development are not inherited.

THE INHERITANCE OF CHARACTERS ACQUIRED BY PLANTS AND ANIMALS IN THE COURSE OF THEIR DEVELOPMENT

In conformity with their antiscientific assertions that the heredity of plants and animals is unalterable (or that the rarely occurring changes are independent of the conditions of life) the Weismannists deny the inheritance of new characters acquired by plants and animals in the course of their development. According to their views plants and animals do not acquire any new properties and characters during their development. Consequently, man is unable to develop new properties and characters in cultivated plants and domestic animals.

Michurin and his followers have proved that these assertions of the Weismannists fail to reflect objective natural laws. Michurinists proceed from the idea that the inheritance of characters acquired by plants or animals in the course of their development is not only possible, but indispensable. "Heredity changes and its complexity increases as the result of the accumulation of new characters and properties acquired by organisms in

successive generations," says Lysenko. If we deny the inheritance of acquired characters then we shall have to deny the development of nature or to explain this development by the operation of mysterious forces. Unless we acknowledge the inheritance of acquired characters it is impossible to give a materialist explanation of the development of living nature and to explain the appearance in nature of new properties and characters, of new organisms with new properties and characters.

Let us take an example from the work of contemporary Michurinists. It is known that in nature there never existed a cotton plant producing coloured fibre. All the known forms of the plant produce either white or dirty brown fibre. If we adhere to the views of the Weismannists and are consistent then we must say that it is impossible to create plants possessing qualities which up to now have never existed in nature. And yet our Michurinists have now proved that such a quality can be developed, can be created in the cotton plant. And they have created a cotton plant with naturally coloured fibre. They have been able to do this due to the inherent capacity of plants and animals to inherit and accumulate properties the development of which is favoured by conditions of life. Guided by the Michurinist theory cotton growers have obtained hybrid organisms which

are particularly sensitive to conditions of life. Thus, by providing the hybrids with the requisite conditions of life they have developed in them the desired properties—properties that the cotton plant never possessed before.

The same law of the inheritance of acquired characters operates in animals. The zootechnicians of the Karavayevo state farm have, under the guidance of S. I. Steimann, created a remarkable new breed of the Kostroma neat cattle. How was this breed created, under what conditions was it formed? The first and foremost condition of success in producing the breed was the abundant and skilful feeding of the animals during the entire period of their growth and development.

A second and no less important factor applied by the animal breeders of this farm was the skilful intensive milking of the cows.

A third factor was the skilful training of the animals and their proper maintenance.

A fourth factor was selection.

On the basis of abundant feeding, intensive skilful milking and proper maintenance of the animals the Karavayevo animal breeders selected the best specimens and the most appropriate were left for breeding. They crossed the best pairs of animals in order to create special lines and families; in the course of many generations they perseveringly and systematically accumulated and fixed

all the valuable and necessary properties and characteristics.

The best record cows of the Karavayevo herd give as much as 15-16 thousand litres of milk a year. The capacity to give such milk yields is hereditary. It has been developed only as a result of the fact that from generation to generation the cows accumulated the capacity to give such yields. To feed its calf the cow biologically requires no more than 200-250 litres of milk. If the cow gives 10 thousand litres of milk and more yearly that means that this capacity has been developed in the course of a number of generations by means of the proper feeding, proper milking, rearing and choice of parental pairs. The capacity to give big yields of milk has been accumulated in a series of generations, it has been transmitted from generation to generation.

Michurin held that under good culture conditions even a wild apple tree can be transformed into a cultivated one, whereas if the rearing is unskilful and careless even the best apple tree will rapidly lose the qualities that interest man. Seeds grown on a highly fertile field slowly but surely improve their breed qualities. Conversely, the most highly productive, best variety seeds quite rapidly lose their culture qualities if grown on a poorly cultivated field. Good maintenance, proper feeding and the choice of the very best for breeding for

a number of generations leads to the development of excellent breed properties in domestic animals. Bad maintenance, scanty and incorrect feeding will rapidly convert the best pedigree cattle into unproductive cattle of inferior breed.

The entire practice of breeding confirms the scientific proposition of Michurinist biology that the inheritance of properties acquired in the course of development is indispensable.

The entire practice of breeding refutes the unscientific assertion of the anti-Michurinists that properties acquired by the organism in the course of its development are not inherited.

THE ORGANISM AND ITS CONDITIONS OF LIFE

The contrast between the Michurinist and the Weismannist trends in biology makes itself manifest already in the definition of the role, tasks, and aims of science.

The Weismannists maintain that science has a basis of its own apart from life. According to their views the basis of life and the basis of science are different. They hold that one idea arises from another, and that each succeeding conclusion follows from the preceding one independent of practice. Weismannists are not disturbed in the least if their theoretical conclusions do not

agree with life, with practice. If such nonconformity occurs, then so much the worse for life, they seem to say. They regard life and practice as something of a lower order, as something of secondary significance. For the Weismannists science stands above life, outside it, divorced from it. Science dictates its laws to life.

As we have already said, in his researches Michurin always proceeded from the fact that every scientific investigation must have as its starting point the demands that life makes, and that every scientific achievement must result in its broadest application in practice. The Michurinists regard biological science as that sphere of man's activity the sole and chief aim of which is to lighten the work of the farmer and to raise the productivity of his labour. The science of biology has but one aim, namely, to explain the phenomena of nature, to disclose natural laws with a view to gain control over nature for the benefit of man. Science and life, i.e., practice, have one and the same basis. Michurinist biology is a science of practical action based on a deep theoretical knowledge of natural laws. Science is created and developed by people, for people, and for human aims. Of course, it is not free from one of the attributes of all human actions, namely, imperfections. But the fact that there exists an efficacious and fruitful science which

helps man to build his life, helps him to make life better and better under our Soviet conditions, indicates that the imperfections of human knowledge do not prevent it from being fruitful.

True science every day brings practical use to people and is always within man's comprehension. Michurinist biology is precisely such a science. The unity of theory and practice is one of the characteristic features of Michurinist biology. In this lies its potency.

The history of biological science is full of examples showing how fruitless were the lives of scientists who, divorced from life, tried to disclose theoretically one or another natural law. All the great fruitful discoveries that contributed to the knowledge of living nature were made by biologists who were guided in their researches by the scientific idea of the unity of theory and practice.

Darwin's teachings—the theory of the evolution of living nature, made its appearance in England, the country where in the XIX century agriculture was most highly developed. This was not accidental. The scientific ideas of Darwinism are the result of the experience accumulated by farmers and animal breeders in the course of many centuries, the experience taken in its most general sense. The materialist idea that constitutes the core of Darwin's theory is the idea of selection. In our days, too, this idea is strictly

scientific, true and efficacious. How did it arise? By means of selection, farmers and animal breeders long before Darwin used to create varieties of plants and breeds of animals. Through the agency of selection they gained remarkable results in the creation of a diversity of cultivated plants and domestic animals. Practical agriculture served Darwin as the material basis for his explanation of the evolution of living nature. In the light of practical agriculture Darwin examined and summarized the enormous mass of material that had been accumulated by naturalists before him.

The appearance of Darwin's theory was a great victory for mankind in the perception of living nature. Darwin's teachings marked the beginning of a qualitatively new stage in the science of living nature. It laid the foundation of materialist biology which proceeded from the passive description of plant and animal forms to the explanation of their origin.

Darwin's theory laid the foundation for the scientific method of studying living nature. He explained the origin of species not by a capacity for development supposedly inherent in the animal organism, but by the adaptation of organisms to conditions existing outside of them, not by the nature of the organism but by the influence of conditions of life. In place of the unscientific idealist explanation Darwin introduced into

science a materialist explanation of the development of nature. In this respect Darwin was kindred to Marx by the nature of his researches. Marx explained the historic development of mankind not by the nature of man but by the nature of the social relations between men that arise when social man exerts his influence upon nature.

The nature of Darwin's investigations, the materialist elements of his teachings were absolutely alien to the idealist world outlook.

Even in the shape that Darwin's theory emerged in his writings it already contradicted the bourgeois idealist world outlook. The further development of materialist science, naturally, still further deepened this contradiction. That is why the post-Darwinian period in the development of biology is characterized to a greater extent by direct attempts to refute Darwinism, by the marked exaggeration of certain erroneous propositions advanced by Darwin than by the development of the materialist elements in his teachings.

Bourgeois biologists have done much to stamp out the Darwinian spirit of research from biological science, to refute the theory of evolution. The most striking expression of the anti-Darwinian trend in the development of bourgeois biology is the reactionary theory of Weismann-Morgan-Mendel which is directed against Darwinism, against the idea of the development of living

nature, against the Darwinian spirit in the study of living nature.

From the very beginning of their investigation of the phenomena of heredity the supporters of Mendelism-Morganism declared that Darwinism hampered the development of the science of heredity. They asserted that it is absolutely of no consequence what views a geneticist—a scientist who studies heredity—holds as regards evolution; it is of no consequence whether he acknowledges the evolution of living nature or not.

Our best Darwinists and among them, first and foremost, those like K. A. Timiryazev, exerted much effort to save the core of Darwinism from vulgarization. While developing Darwinism K. A. Timiryazev at the same time waged a decisive and ceaseless struggle against Weismannism and Mendelism, doing much to shatter and expose these trends.

A still sharper struggle with Weismannism was waged by Michurin in his time. And this was not accidental.

Michurin laid down the basis of the science of controlling the nature of plants. "These foundations have wrought a change in the very method of thinking when dealing with problems of biology." (*The Situation in Biological Science,* p. 46.) In Michurinist biology the Darwinian spirit of investigation has not only found its

complete realization, but has been further developed. In the Michurinist theory "Darwinism has not only been purified of its deficiencies and errors and raised to a higher level, but has undergone a considerable change in a number of its principles. From a science which primarily *explains* the past history of the organic world, it is becoming a creative, *effective* means of systematically mastering living nature, making it serve practical requirements." (*Ibid.*, p. 47.)

The separation of science from life mentioned above finds its peculiar continuation in the teachings of the Weismannists who divorce the organism from its conditions of life. Professor Paramonov, for example, in his *Textbook on Darwinism* (1945) wrote: "The organism is an independent system, and the external environment is another system. Both these systems develop on the basis of entirely different laws. . . . The direction of the changes in the environment and of the variability of organisms are independent of each other."

That is plain enough. But this clearly formulated postulate completely fails to reflect the true laws of nature.

It is now known that higher plants together with the minutest organisms transform granite into dust and later into fertile soil. The succession of plant associations, as has been comprehensively shown by V. R. Williams, determines the

entire century-old process of soil formation. Soil is the product of the activity of plants and animals. Forest plant associations lead to the formation of podzols. In its turn the forest is replaced by herbaceous meadow vegetation. On the soils where meadow grasses grow great masses of organic substance accumulate. Big accumulation of organic substance lead to the bogging of the soil, to the development of marshes. As time passes the marsh stage in the soil-forming processes is succeeded by the development of chernozem. And so on. V. R. Williams disclosed the directed trend of the soil-forming process in nature. He demonstrated that this directiveness is constantly determined by the activity of plants and animals.

Nowadays no one denies the decisive influence of plant and animal organisms on their habitat.

In their turn, Michurin and Lysenko discovered that it is possible to alter the nature of plants in a given direction by bringing conditions of life to bear upon them. *The organism and its environment develop as a unity.*

The variability of the environment is determined by the activity of plants and animals. The environment, the conditions of life determine the variability of plants. In this unity are concealed the motive forces of the development of living

nature. This is the point of view held by materialist biologists.

But the views of Weismannists are different. According to them organisms may develop in one direction and their environment in the opposite direction. These directions may coincide only by pure chance.

After divorcing the organism from conditions of life the Weismannists, as pure idealists, look for the motive forces of the organism's development within the organism itself.

According to the Weismannists there exists inside the living body a special hereditary substance which is distinct from the living body. The hereditary substance contains the pattern of the entire adult organism and the latent forces that are to realize this pattern. In the hereditary substance is predetermined what the external form of the organism will be like, what properties it will possess and how long it will live. The hereditary substance controls all the functions of, and all the changes in, the living body. But it itself is completely independent of the body, and still more of conditions of life. The hereditary substance is immutable and immortal, it is transmitted from one generation to the other in an unaltered form and serves as the basis of life.

Plant and animal cells have nuclei. As the stained sections show, when in the process of de-

velopment the nucleus divides, it disintegrates into separate differently shaped bodies. These bodies are called chromosomes. The chromosomes differ in length and consist as it were of separate minute particles. The Weismannists have named these particles genes. According to the theory of the Weismannists these genes are the hereditary substance. It is only through this substance that heredity is transmitted from one generation to another.

The fallacy of the Weismannist views that the body contains a special hereditary substance has been proved by the Michurinists with the aid of vegetative hybrids. If we graft a cutting of a tomato producing white fruits (Albino) on the stem of a tomato bearing red fruit, the white-fruit cutting will grow and feed on the substances produced in the leaves and roots of the red-fruit variety. The nuclei (and therefore the chromosomes) are not transmitted from the red-fruit variety to the cutting of the white breed. Only an exchange of nutritive substances takes place. And yet it has been proved that as a result of such an exchange hybrid organisms may arise. If the described grafting is properly effected (the way to do it may be learned from the works of Michurin and Lysenko) some red fruit will appear on the cutting of the white variety. If we now take the seeds of the red fruits growing on the white cutting and plant them, some of the

resulting plants will manifest the characters of both breeds of tomatoes—the red and the white. In the grafting described the union of two breeds into one takes place only as the result of nutrition, without any exchange of chromosomes.

These graftings show that there is *no hereditary substance in plants,* that the organism has no organ of heredity. Heredity is the property of the living body as a whole and of all of its parts. This property is determined by the entire preceding development of the given form of organism. It is the preceding development accumulated by the organism that goes to make up the property of heredity. "The preceding development is the basis, the foundation of the future development. The distant and the immediate future development cannot be separated from the preceding one." (T. D. Lysenko.) The future development of the organism is based on its past historic development.

To understand this development, to understand the path the organism has traversed and also its prospective path, one must study the organism and its conditions of life as a unity.

Michurinists have proved that it is impossible to study the organism divorced from its conditions of life. We know that fish live in water. It is enough to take the fish out of the water and we shall have to do with a dead fish instead of

a living one. Rice grows in fields covered with water. If rice is deprived of the water it perishes. Conversely, if a wheat field is flooded the crop will perish immediately.

If we wish to learn the laws of development of wheat, rice or fish we must study their development, their life, only in unity with their conditions of life. In this unity are concealed the causes underlying the changes in the heredity of organisms, the causes that determine the characters and properties of the organism, etc.

If in the plant or animal we alter the cells from which a new generation arises, then from these altered cells an altered organism will develop. This proposition is universally acknowledged by biologists. It is as much a truth as that a wheat grain gives rise to a wheat plant or an oat grain to an oat plant. The question is how to alter the cells that serve as the basis for the development of a new generation. Here another important question inevitably arises, namely, how can the cell be altered in such a way as to obtain an organism possessing the qualities that man needs? For example, how can the cell be changed in such a way as to enhance the property of winter hardiness in winter wheat? The same question may be put in another way. *Is it possible to alter the germ cells systematically, with a definite aim and in a given direction?* This formulation reflects

the substance of the controversy which is going on in the science of biology.

The answers to the questions raised will be different depending on how the basic question is answered—the *question concerning the nature of the relation between the organism and its conditions of life.*

The Michurinists have proved that organisms alter their environment, while the environment, the conditions of life, in their turn, alter the nature, the heredity of organisms. Proceeding from this the Michurinists study the means of altering the germ cells by altering the organism's conditions of life. Altered conditions of life change the process by which the body of the organism is built, including the building of the chromosomes and the germ cells as such from which the succeeding generation will arise. Michurinists make a thorough study of the problem of how and when it is necessary to bring conditions of life to bear on the developing organism in order to alter its heredity, its demands on conditions of life. The directed alteration of germ cells, the alteration of heredity with a definite aim may take place only in approximately the following way. *Altered conditions of life change the body of the organism; the altered body in the course of its development forms structurally altered sex cells. From the altered sex cells altered organisms develop.*

According to the Weismannists, unknown and unknowable forces concealed within the cells, to be more exact, inside the cell nuclei, are the prime cause of change in organisms. Such assertions are antiscientific.

The Michurinist path, on the other hand, is corroborated by practical agriculture as a whole. It is based on the historical development of organisms in unity with their conditions of life.

In their researches the Michurinists are guided by the only correct world outlook—by dialectical materialism, they are guided by the great teachings of Marx, Engels, Lenin and Stalin. In this lies the reason of the successes gained by Michurinists in the past, in this lies the guarantee of the still greater successes that Michurinist biology will gain in the future.

Michurinists are developing materialist biology. And materialist science always has gained and will continue to gain victory over idealism, no matter in what form the latter penetrates into science. Only one science is true and all-powerful, namely, materialist science. The Michurinist science of biology is just that kind of science.

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